Container Handbook

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Captain AG Winfried Strauch

Securing the product in the container

Preface

The global economy depends on the smooth exchange of goods. Any damage results in a waste of resources. Loss prevention measures are not only economically necessary but also directly protect the environment.

Surveys of transport practice have revealed that almost seventy percent of all packed containers, swap-bodies, road and rail vehicles or other cargo transport units exhibit shortcomings in packing and load securing which could result in damage. The aim of this section of the Container Handbook, "Securing the product in the container", is to prevent damage due to negligent packing and inadequate load securing.

The author's original intention was to present mainly good examples of packing and to complement these some bad examples as a deterrent. However, the real situation was so bad that he was unfortunately compelled to write the Handbook in such a way that lessons could be learnt from the load securing errors which had been made. Detailed comments are provided as to how these errors could be remedied or avoided. The author very deeply regrets the fact that so very few properly secured container loads could be found in practice which could serve as good examples for a Handbook.

Even a Handbook which has been edited and updated over many years cannot take account of all the variants encountered in practice, and the present Handbook itself cannot make any claim to completeness, being less than comprehensive or perfect in many parts. Nevertheless, it is being made publicly available in its present form in the hope that it will make at least some contribution to preventing damage and loss. The author hopes that it will be possible gradually to update this Handbook so that it will become a useful source of advice to anyone responsible for packing and securing cargo transport units.

Comments

Quotations from laws, regulations and other rules were valid at the time when the text was written. One or another regulation may have been rescinded, supplemented or amended since then. Please bear this in mind appropriately.

1 Introduction

1.1 The history of the container

In May 2001, Malcolm P. McLean, the "Father of Containerization", died aged eighty-seven. He used to say that he had the idea of rationalizing goods transport by avoiding the constant loading and unloading from one means of transport to another way back at the end of the 1930s at the port of Hoboken, when still operating as a small-scale hauler. To start with, McLean would load complete trucks onto ships, in order to transport them as close as possible to their destination. The development of standardized containers and trailers, moved by tractors, made it possible to ship just the trailers with the containers, so saving on space and costs. Later, the trailers were also left behind and the ships transported just the containers.

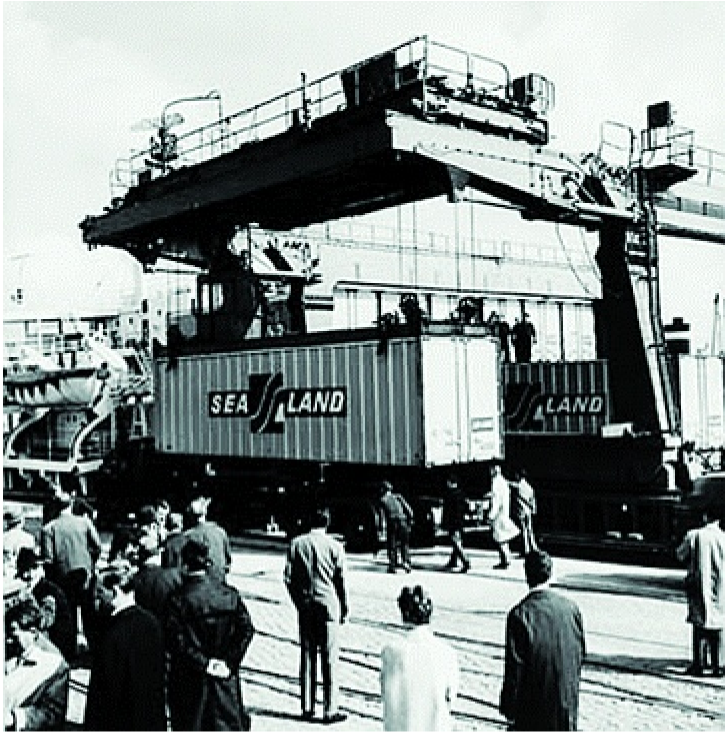
Shipowners were more than a little skeptical about McLean's idea. This prompted him to become a shipowner himself and he appropriately named his company Sea-Land Inc. At the end of the 1990s, McLean sold his company to the Maersk shipping company, but his company name lives on in the name Maersk Sealand.

In the literature, the "Ideal X" is mentioned as the first container freighter. This ship left Newark on 26th April 1956 carrying fifty-eight containers, which it transported to Houston. The first ship designed to carry only containers is the "Maxton", a converted tanker, which could carry sixty containers as deck cargo. That was in 1956.

Another decade passed before the first container ship moored in Europe. The first container on German soil was set down by the "Fairland" at Bremer Überseehafen on 6th May 1966. The first containers used by SeaLand in Northern Europe were 35' ASA containers, i.e. they were constructed to American standards. In other regions, 27' ASA containers and other ASA dimensions were often used. Shipowners in Europe and Japan quickly recognized the advantages of the container and also invested in the new transport technology.

Since American standards could only be applied with difficulty to conditions in Europe and other countries, an agreement was eventually reached with the Americans after painstaking negotiations. The resulting ISO standards provided for lengths of 10', 20', 30' and 40'. The width was fixed at 8' and the height at 8' and 8' 6". For land transport within Europe, agreement was reached on a 2.50 m wide inland container, which is mainly used in combined road/rail transport operations.

The majority of containers used worldwide today comply with the ISO standard, with 20'- and 40'-long containers predominating. For some years, the ISO standard has come repeatedly under pressure. As stowage factors increase for most goods, many forwarders want longer, wider and higher containers, preferably all at once. Some shipowners have given in to the pressure and containers of dimensions larger than provided for by the ISO standard are now encountered distinctly more frequently. "Jumbo" containers of 45' and 48' in length, widths of 8'6" (2.60 m) and heights of 9'6" (2.90 m) have been in existence for some years. Efforts to build even larger containers, e.g. 24' (7.43 m) and 49' (14.40 m) boxes 2.60 m wide and 2.90 m high, are mostly confined to the USA. Even 53' long containers have been approved for use for some time throughout the USA, while some states will even allow 57'. In Europe and on other continents, narrower roads are a limiting factor. Developing countries are understandably against changing the standards. More details are given in the section entitled "Container dimensions and weights".



1.2 Container flows

The huge investments made in containerization have paid off and container traffic is still continuing to grow. Although growth will not be as unbridled as in the past, it will continue until all conventional transport operations have, within a container's limits of capacity and weight, been containerized.

By then, it is estimated that there will be some 8000 ships in operation with a total slot capacity of nine to ten million standard containers. There will be approximately the same number of containers ashore being packed or unpacked, awaiting stuffing or unstuffing or being transferred. The majority of these containers are standard 20' box containers. While there are special containers for many applications, growth rates for these are not significant.

From the standpoint of container traffic, it would be ideal for there to be a balance between incoming and outgoing containers in a particular region, not only in terms of numbers, but also in terms of container type and weight. Unfortunately, such a balance is not achievable. There will thus always be empty containers to be transported in one direction or another. From the shipping company's standpoint, general purpose containers usable in any circumstances would be a major advantage. Forwarders, on the other hand, would prefer special containers if they could be carried at identical cost, as packing and securing is much easier in a special container than in a standard container.

For example, steel sheet in coils can very quickly be loaded onto coil containers and straightforwardly secured. They are rather more difficult to pack and secure on flatracks, while they are particularly difficult to pack and secure in box containers. Shipowners accepting containers loaded with coils for transport to Colombia would, if the rolls of sheet steel were shipped in coil containers, also have to take a large number of empty standard ventilated containers to Colombia in order to transport coffee from Colombia to Europe. Moreover, the coil containers, which are of no further use in Colombia, would have to be transported empty to somewhere where they could be used again. As a result, steel sheet in coils will be transported to Colombia in "coffee containers" which are less suitable for carrying such cargoes.

Another example: in order to save on the higher freight costs associated with using tank containers, flexitanks are placed inside normal standard box containers, the walls of which are frequently damaged by surging of the liquid in the flexitanks.

A further example: containers exported from Europe to East Asia are, on average, heavier than those imported from East Asia. If it is to be possible to export the bulkier cargoes from East Asia, empty containers will have to be transported to East Asia. If many 40' containers are required to carry "light" cargoes from East Asia to Europe, it is sensible also to use these containers in Europe to carry "heavy" cargoes to East Asia. Users of these containers get plenty of transport space, the volume of which is not actually required, plus a "securing problem" because such containers cannot be tightly packed.

The majority of the world's container stocks are owned by shipping companies. Quite a few are, however, leased in both large and small numbers to shipowners or other interested parties by leasing companies. Some forwarders ship goods in their own containers, but these are generally special containers for bulk cargoes, tank containers for chemicals or beverages or coil containers for the steel industry etc.

1.3 Maritime transport of containers

Introductory remarks

This section is intended to provide the interested layperson with some basic information about how to stow and secure containers on board ocean-going vessels, so as to give him/her a better idea of the problems involved and possibly of how to select the appropriate carrier. Those actually involved with securing containers on board ships should refer to other specialist literature.

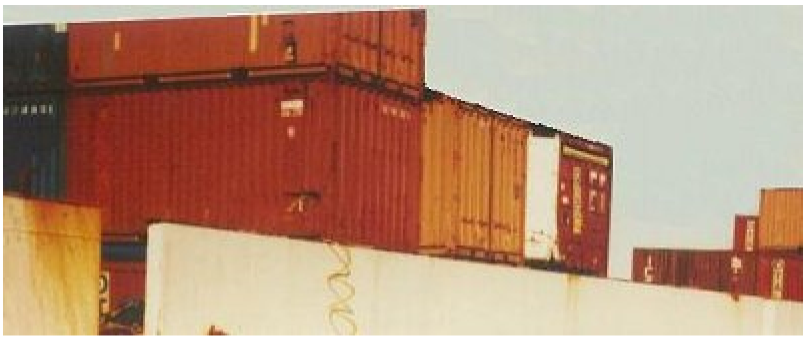
General on-board stowage

On most ships which are specially designed for container traffic, the containers are carried lengthwise:

Containers stowed lengthwise fore and aft stowage on board a ship

This stowage method is sensible with regard to the interplay of stresses in rough seas and the loading capacity of containers. Stresses in rough seas are greater athwartships than fore and aft and the loading capacity of container side walls is designed to be higher than that of the end walls.

However, on many ships the containers are stowed in athwartships bays or are transported athwartships for other reasons. This must be taken into consideration when packing containers and securing cargo.



Containers stowed athwartships (athwartships stowage) on board a ship

This stowage method is **not** sensible with regard to the stresses in rough seas and the loading capacity of containers. Stresses in rough seas are greater athwartships than fore and aft but the loading capacity of container end walls is lower than that of the side walls.

Containers stowed both ways on board ship

Even unusual stowage methods like this, where some of the containers are stowed athwartships and others fore and aft, are used, but they require greater effort during packing and securing operations.

The above two pictures show how important it is to find out about the various carriers and their way of transporting containers, either in order to rule out certain modes of transport or to be able to match cargo securing to mode of transport. If the method of transporting a container is not known, then packing and securing have to be geared to the greater stresses.

General securing information

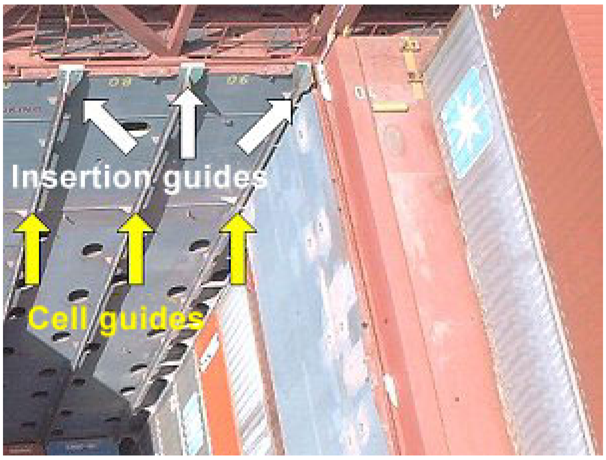
When securing containers on board, the stresses resulting from the ship's movements and wind pressure must be taken into account. Forces resulting from breaking-wave impact can only be taken into account to a certain degree. All the containers on board must be secured against slippage and toppling, with care being taken to ensure that the load-carrying parts of the containers are not loaded beyond admissible levels.

Except in the case of individually carried containers, securing is effected by stacking the containers in vertical guide rails or by stowing them in stacks or blocks, the containers being connected together and fixed to parts of the vessel.

Securing in vessel holds by cell guides alone

Cell guides in an all-container ship

Virtually all all-container ships are provided with cell guides with vertical guide rails as securing means for hold cargoes. The greatest stress the containers are exposed to stems from stack pressure. Since the containers are not connected together vertically, lateral stress is transmitted by each individual container to the cell guides When positioned in such cell guides, individual containers are not usually able to shift. If the corner posts of one of the containers at the bottom of a stack collapse under excessive pressure, containers stowed above it generally suffer only slight damage. The risk of damage to containers in adjacent stacks is kept within tight limits.



Guide rails of two adjacent slots

The containers are guided by these rails of the cell guides during loading and unloading. The photo shows clearly that the upper ends of the guide rails each take the form of insertion guides.

Securing in vessel holds by cell guides and pins

Feeder ships, multipurpose freighters and container ships in certain regions have to be particularly flexibly equipped, in order to be able to carry containers of different dimensions. To this end, convertible stowage frames have been developed, in which 20', 24½', 30', 40', 45', 48' and 49' containers may be stowed securely without appreciable delay.

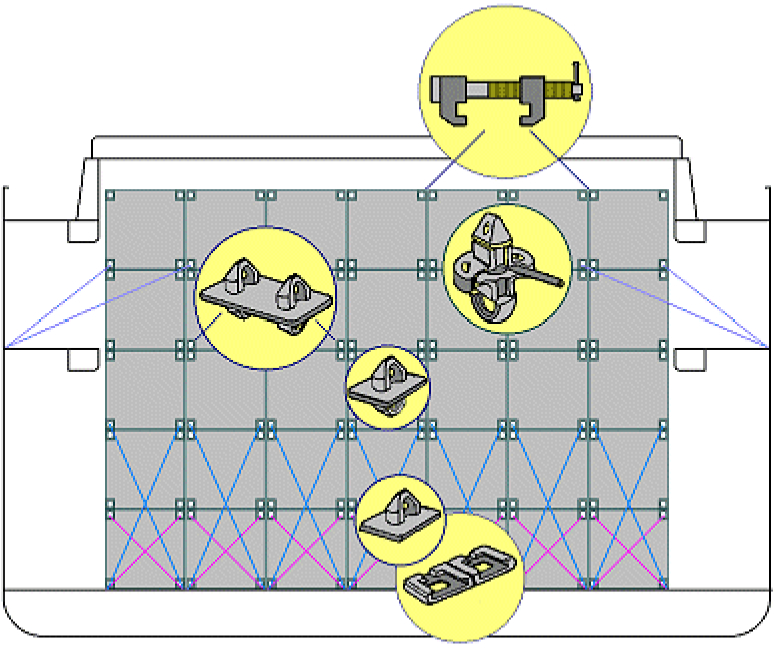
Most of these frames are produced as panels which are brought into the required positions by cranes. At the bottom they mainly have fixed cones, which engage in pockets welded into the tank top area. At the sides, the frames are secured by pins, which engage in bushes which are let into the wing bulkheads. Such frames are often man-accessible, so that the containers can be locked in place by means of pins.

If it is necessary to be able to carry containers 2,500 mm wide, the frames are arranged on the basis of this dimension. To secure standard containers of normal width, closure rails are then fitted on both sides of the guide rails by means of screw connections. If necessary, these adapters may be removed.

Removable container guides have also been developed and constructed for multipurpose freighters, reefer vessels and the like. Such guides allow containers to be carried in regular or insulated holds without any risk of damage to the holds themselves. If other cargoes are carried, the stowage guides may be removed using ship's or shore-based loading or lifting gear and deposited in special holders on deck.

Securing in vessel holds by conventional securing and stacked stowage

On older, conventional general cargo vessels and multipurpose freighters, stacked stowage methods are used in the hold, combined with various securing methods:

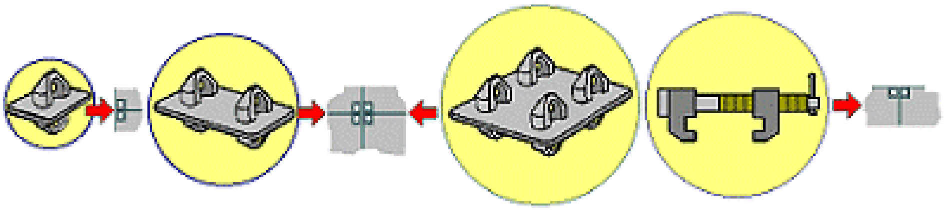


Example of stacked stowage with conventional securing

The lower containers stand on foundations capable of withstanding the stack pressures which arise. Dovetail foundations, into which sliding cones fit, are provided to prevent slippage. The containers are connected together by single or double stacking cones or twist locks. The entire stack or container block is lashed using lashing wires or rods and turnbuckles. This system entails a lot of lashing work and material and, moreover, is less secure than securing in cell guides.

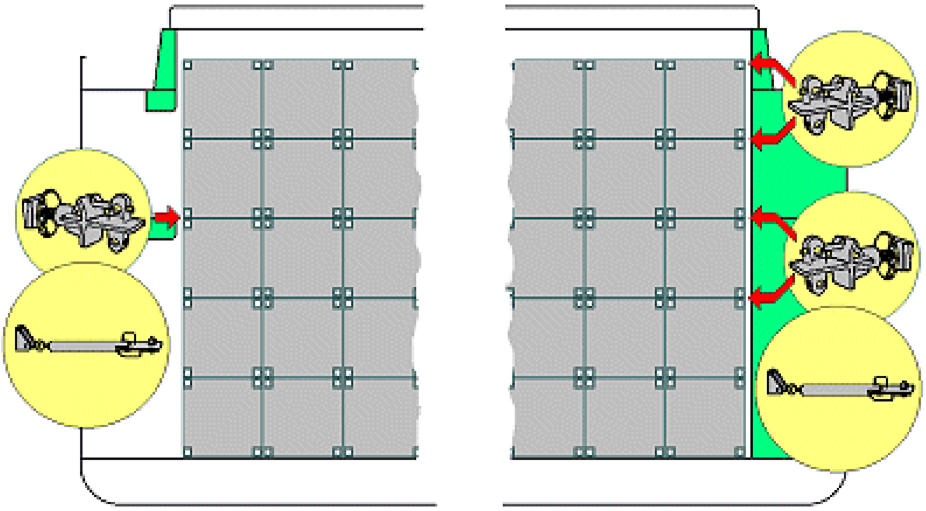
Securing in vessel holds by block stowage and stabilization

This securing method is found less and less frequently, but it is still found on some conbulkers and other multipurpose freighters. Containers are interconnected horizontally and vertically using single, double and possibly quadruple stacking cones. The top tiers are connected by means of bridge fittings.



Fastening containers together

To the sides, the containers are supported at their corner castings with "pressure/tension elements".



Examples of block stowage method with stabilization

This type of container securing has two marked disadvantages:

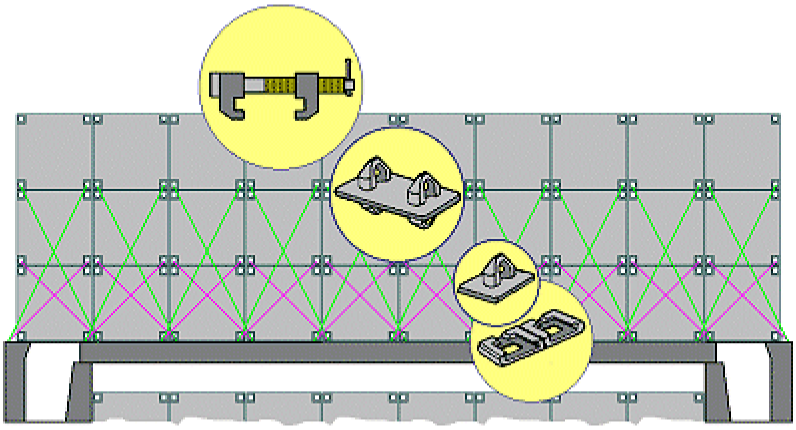
- If an individual container breaks, it is not just one container stack which is affected, but the whole container block.
- Due to dimensional tolerances and wear and tear to the stacking cones, the entire block can move constantly in rough seas. This causes the intermediate stacking cones to break and an entire block may collapse.

Securing on deck using container guides

On some ships, containers are also secured on deck in cell guides or lashing frames. Some years ago, Atlantic Container Lines used only cell guides on deck. Certain ships belonging to Polish Ocean Lines had combined systems. In other ships, cell guides can be pushed hydraulically over the hatch cover as soon as loading below deck is completed and the hatches have been covered up.

Securing on deck using block stowage securing

This method was used a lot in the early days of container ships, but has been used less and less in recent years for economic reasons.



Example of block stowage securing on deck

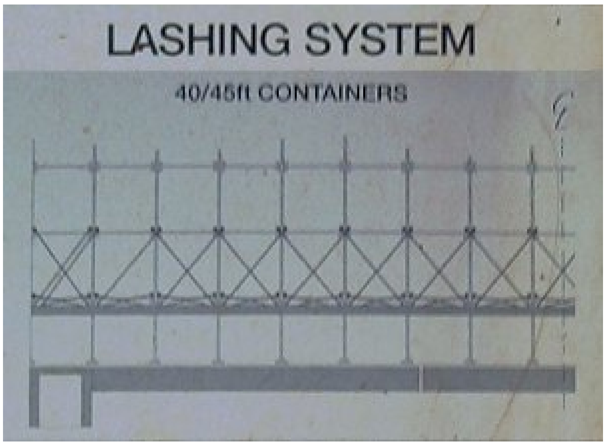
The containers in the bottom layer are positioned in socket elements or on fixed cones. Double stacking cones are used between the layers and the corner castings of adjoining containers are connected at the top by bridge fittings. The containers are held together over the entire width of the ship or hatch cover by cross lashings. A distinct disadvantage of this method is reduced flexibility when loading and unloading, since adjoining containers have always to be moved as well if access to a particular container is required.

Numerous variants, not listed any greater detail here, are available for attaching the lashings. Sometimes the lashings from different stacks cross one another.

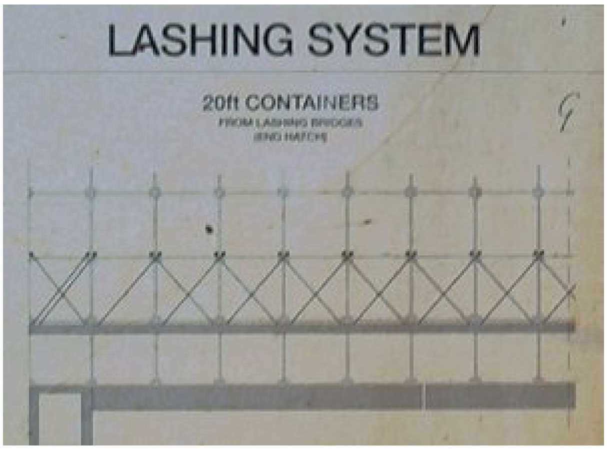
Crisscross lashings from different container stacks

This securing method is being used increasingly in very large container ships.

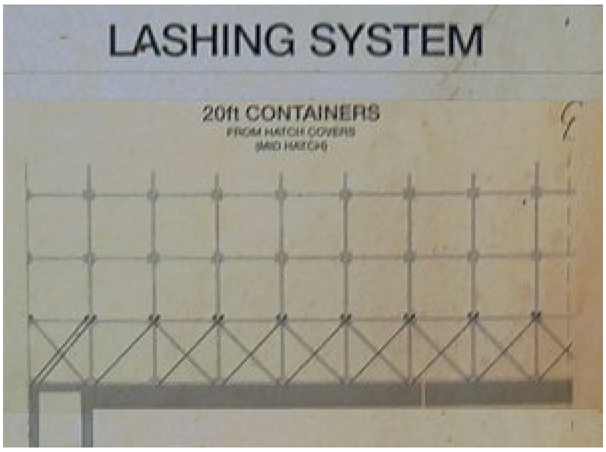
Instructions for lashing on board ships are displayed in obvious places.



Lashing system for 40' and 45' containers



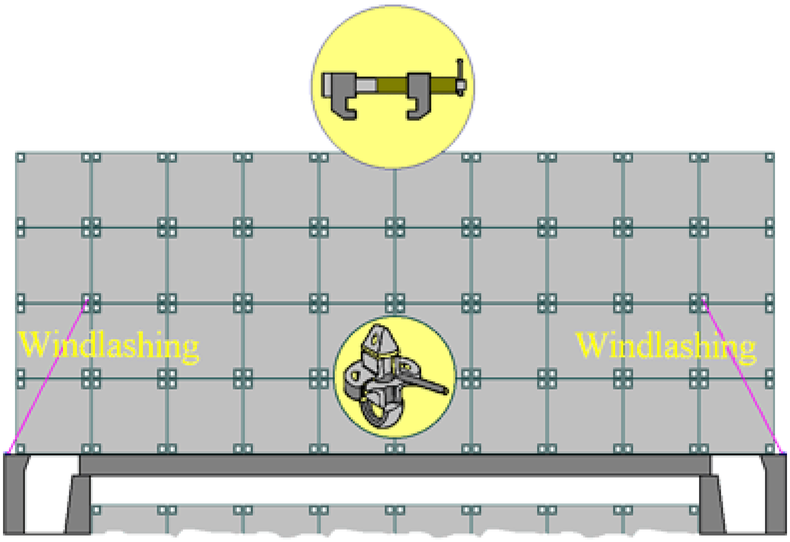
Lashing system for 20' containers from the lashing bridges of the end hatches



Lashing system for 20' containers from the hatch covers of the middle hatches

Securing on deck using stacked stowage securing

This securing method is the one used most frequently. Cargo handling flexibility is its key advantage. The containers are stacked one on top of the other, connected with twist locks and lashed vertically. No stack is connected with any other stack. The container lashings do not cross over the lashings from other stacks, except for the "wind lashings" on the outer sides of the ship.



Principle of stacked stowage securing

Securing of on-deck containers with lashing rods and twist locks

Securing of on-deck containers with twist locks and chains

Securing of a 3-tier stack on board a semi-container ship

Obviously, a container stack of this kind can topple if it is not adequately secured.

An absence of special equipment for securing containers and unfavorable stowage spaces increase the risk for container cargoes. "Sloppy" carriers should be avoided wherever possible. This applies quite generally, not only to the operators of aging ships. Timely information about as many as of the circumstances and procedures encountered during carriage as possible can be extremely useful.

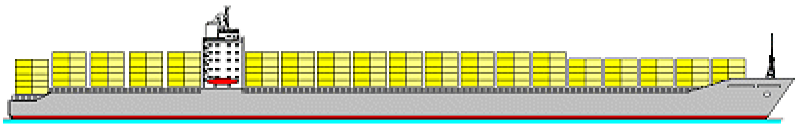
1.3.3 Container stowage plans

Working stowage plans are drawn up to assist in advance planning. Master plans definitively document the positioning of containers on board.

The bay-row-tier system follows a system of numerical coordinates relating to length, width and height. The stowage space of the container on board the ship is unambiguously stated in numbers and is (almost always) recorded in the shipping documents. It is then also possible to establish at a later date where the container was carried during maritime transport.

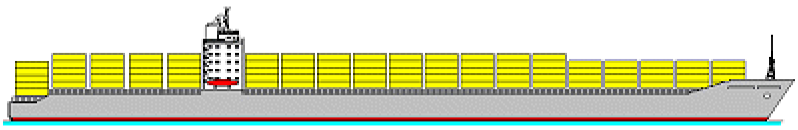
Principle of bay-row-tier coordinates

According to this principle, bays are the container blocks in the transverse direction, rows are the lengthwise rows and tiers are the vertical layers.



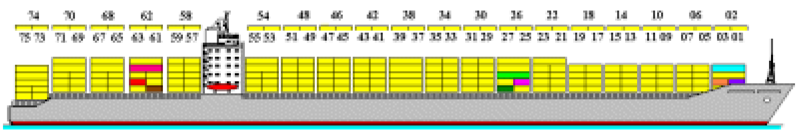
Thirty-eight 20' container bays on a ship

Theoretically, the thirty-eight bays could be numbered continuously from 1 to 38. However, that would only be sensible if only 20' containers could actually be loaded.



Nineteen 40' container bays on a ship

If the ship could only transport 40' containers, the nineteen bays could be numbered continuously from 1 to 19.

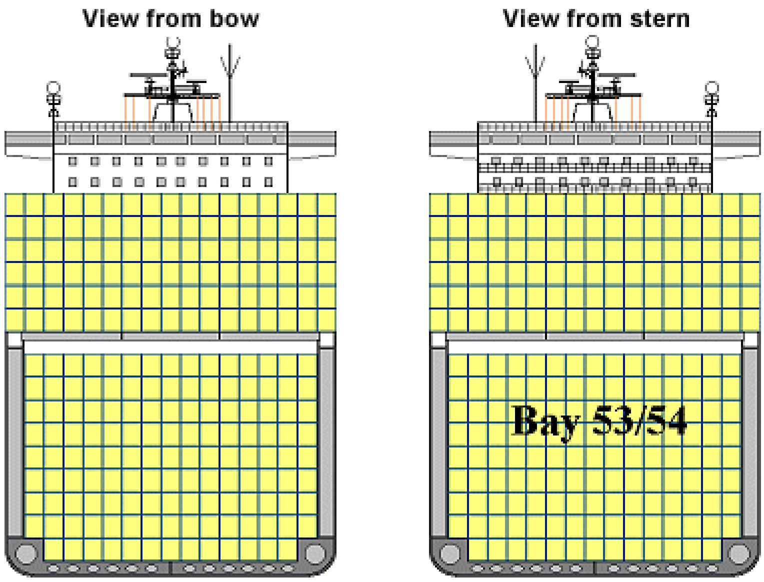


Bay numbering system

Since, however, the ship can transport both 20' and 40' containers, the bay spaces for 20' containers are numbered throughout fore to aft with odd numbers, i.e. in this case 01, 03, 05 and so on up to 75. The bay spaces for 40' containers are numbered throughout with even numbers: 02, 04, 06 and so on up to 74.

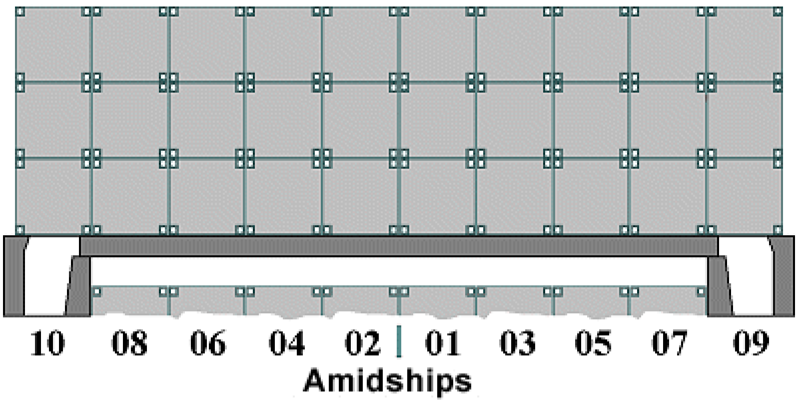
The purple 20' container in the first bay has the bay number 01. The light-brown 20' container in the second bay has the bay number 03 and the light-blue 40' container, which occupies a space in the first and second bays, has the bay number 02. The magenta-colored container has the bay number 25, the dark-green number 27 and the light-green number 26.

To illustrate a cross-section through a bay, one needs to imagine that one is standing in front of or behind the ship.



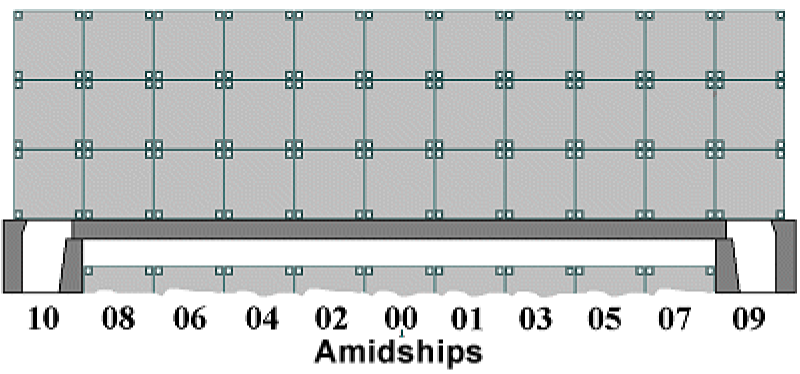
In the case of bay plans, the respective bay is always viewed from behind.

The rows of containers on a ship are numbered with even numbers from the center leftward and odd numbers from the center rightward.



Row numbering where there is an even number of rows

Where there is an odd number of rows, the middle row is numbered 00.



Row numbering where there is an odd number of rows

Numbering of the port rows on board ship

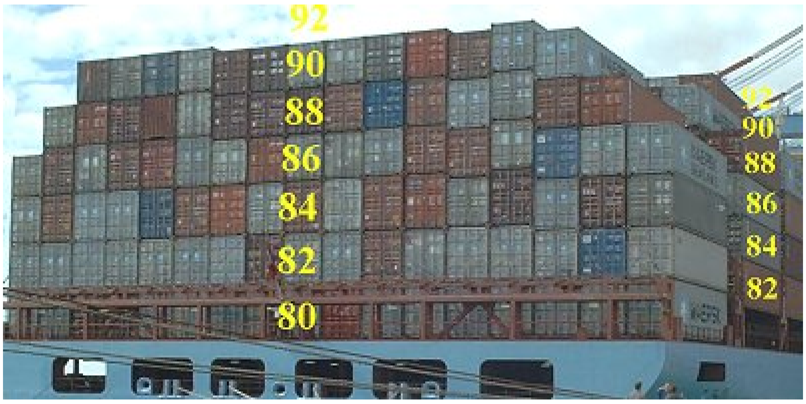
On close inspection, the photograph shows left-hand row 16, which is designed to be filled with containers only on deck, and rows 14, 12, 10, 08, 06, which may be filled both on deck and in the holds. Rows 04, 02, 00, 01 and 03 are likewise designed to be occupied in the hold and on deck. However, the hatch covers are already on in this case.

Numbering of the starboard rows on board ship

Rows 05, 07, 09, 11 and 13 are still empty in this bay. Row 15 is designed only for on deck occupation, and is still free in this bay.

Row numbers of the aft bay of a ship

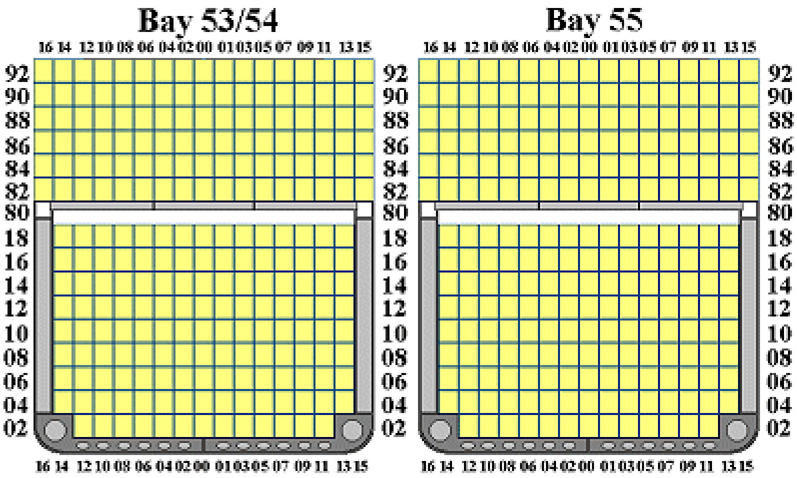
The container tiers are numbered with even numbers, starting from the bottom. The conventional way is start with 02 in the hold and then count up with 04, 06 etc. In the case of deck cargoes, it is conventional to start numbering with 80 or 82. There are sometimes slight differences between ships.



Numbering of horizontal container layers, or tiers

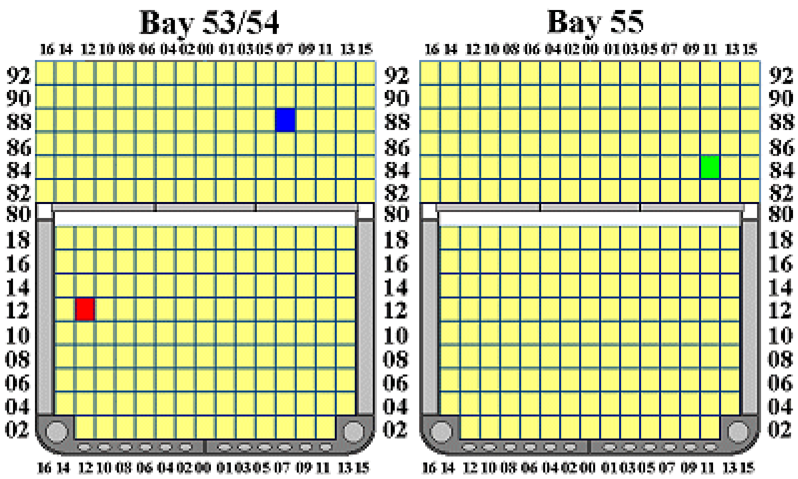
On this ship, the containers standing directly on the main deck are numbered 80 and those standing on the hatches are number 82. The number is incremented by two for each higher layer.

These bay, row and tier numbers are noted in the bay plans.



Bay plan

The loaded containers, with their alpha prefix, their container numbers, the port of destination or discharge and other important details are noted in the bay plans.



Color-labeled containers in a bay plan

According to the bay-row-tier system, the colored containers were given the following stowage space numbers:

- a 20' container in the red-colored slot: 531212
- a 40' container in the blue-colored slot: 540788
- a 20' container in the green-colored slot: 551184

The system illustrated is the most widely used. However, other numbering systems do exist, in which the coordinates are stated in a different order, for example row-bay-tier systems and similar combinations. On ro/ro ships, the slots are usually organized along lanes running lengthwise. In individual cases and if required, such information may be obtained from shipping companies, cargo-handling companies or other competent persons.

1.4 Containers and insurance (by Matthias Rühmann)

1.4.1 General

Approximately three sixths of all the containers used worldwide belong to leasing companies, another two sixths to shipping companies and the final sixth to other owners*.

1.4.2 Containers and cargo insurance

In principle, cargo insurance only covers claims relating to material damage to goods.

Exceptionally, the proprietor's interest in the container as packaging may also be insured if a special agreement is reached or through inclusion thereof in the damage liability invoice value. Interest in a leased container is not in principle insured.

The purpose of packaging is to allow transport of goods and to protect them from possible damage. If the above aim has been fulfilled, it is most common for only the packaging to be damaged, and not the goods.

ADS 1919 or ADS 1973/1994 (ADS = Allgemeine Deutsche Seeversicherungsbedingungen [General German Marine Insurance Conditions]) and the DTV - Güterversicherungsbedingungen [Association of German Transportation Insurers - Cargo insurance conditions] do not include any particular provisions in this respect. The following may be inferred from the general principles of transport insurance law*:

If the packaging does not have any separate, intrinsic value, no independent loss may occur. Packing paper, which is discarded after the arrival of the cargo and suffers wear during transport, cannot therefore form the basis of a claim for damages. If the goods have reached their destination, the only relevant question is whether the goods have suffered loss and not whether the packaging is damaged. This also applies to cases.

Consideration can only be given to any such claim if the goods have depreciated in value solely as a result of the damage to the packaging. This is the case for example with preserved foods and certain branded goods. Another example is cement, which retains its normal commercial value only in its original bags. If cement which is in itself sound is sold in unmarked bags because the original bags have been damaged, it automatically suffers depreciation. In such cases, compensation may be paid despite the damage being limited to the bags.

Otherwise, compensation may only be paid for packaging damage if a separate value is assigned to the packaging either in the policy or in the invoice (e.g. barrels or containers). This only applies if the packaging is expected to have a longer service life than the duration of one transport operation.

A different matter entirely is the cost of repairing or replacing packaging, if this has to be performed en route. It may be possible to claim compensation for these costs, though not in the form of packaging losses but as loss minimization costs, which are expended to return the goods to a transportable state and to prevent losses on the remaining insured journey. For such a claim to be allowable, the packaging must have been satisfactory at the start of the journey. If the journey is complete or the remainder of the journey is uninsured, the insurer will not meet such costs, because, the insurance contract having expired, no more insured losses can be incurred.

Because of the uncertainties involved in using cargo insurance to insure a container as packaging, it is better to provide separate hull insurance by way of special conditions for container insurance. As far as the proprietor's interest is concerned, double insurance cover may then be provided by the cargo insurance and the container & hull insurance.

1.4.3 Containers and container & hull insurance

Containers cannot be easily defined as either hull or cargo. To distinguish them more readily from insurance for the container cargo, the special conditions are known as hull clauses. Nonetheless, the nature of the cargo remains the predominant factor, for which reason the special conditions should only be agreed in conjunction with DTV cargo insurance conditions.

In general, therefore, containers are not covered as packaging by cargo insurance, but instead by special all-risks insurance by way of special conditions for container insurance. However, compensation is only paid for damage to machinery and tarpaulins, if it is an immediate consequence of an accident involving the means of transport or of stranding.

The special conditions may also be applied to leased containers, if the lessee bears the risk. However, to clarify the situation, this should be expressly stated in the corresponding "written conditions".

1.4.4 Liability of transport company

1.4.4.1 Container provided by shipper

Whether the shipper uses his own container or one borrowed, rented or leased from a third-party, he is using the container as packaging.

The transport company is liable for material damage to the cargo and the container under the corresponding carriage conditions, since, when calculating liability, the gross weight is to be understood to mean the total weight including packaging.

1.4.4.2 Container provided by carrier

There are several different conceivable situations, whether the carrier uses his own container or one borrowed, rented or leased from a third-party*:

Permanently mounted container

If the container is mounted permanently on the chassis of a truck. i.e. is completely fixed thereto, it fulfills the requirements of a fundamental component of the vehicle for the purposes of § 93 BGB [German Civil Code].

The transport company is liable for material damage to the cargo under the corresponding carriage conditions. This liability does not include the weight of the container, since the contract of carriage relates only to the cargo and not additionally to the container.

Leased containers

If, on the express wish of the shipper, the carrier makes available to said shipper a freely handleable container which is not connected permanently to the vehicle, for instance because the shipper's intention is for the container to be transferred between several means of transport during carriage, the carrier will generally demand additional remuneration for handover of the container. This gives rise to a leasing agreement between the carrier and the shipper.

The transport company is liable for material damage to the cargo under the corresponding carriage conditions.

Material damage to the container is covered by the content of the leasing agreement.

Containers as ancillary transportation equipment

If the carrier makes the container available to the shipper to simplify transport without any special additional agreement of the type mentioned above, the contract of carriage as a rule relates only to the transport of cargo in a vehicle suitable therefor.

The transport company is liable for material damage to the cargo under the corresponding carriage conditions. This liability does not include the weight of the container, since the contract of carriage relates only to the cargo and not additionally to the container.

1.4.5 Reference

Further information may be found under the heading "Container legislation" (only available in German).

1.5 Responsibility for packing

Storage, cargo handling and transport of goods are covered by both national and international regulations, which set out minimum requirements for treatment of goods, vehicle use etc. Public regulatory guidelines are supplemented by private agreements and terms and conditions of business. Careful packaging and marking of goods for dispatch should be accompanied by proper packing, stowing, securing and unpacking. When carrying hazardous materials, additional provisions must be taken into account with regard to packaging, labeling, documentation etc.

A high percentage of goods are intended for carriage by combined road, rail, water and air transport, whether through repeated transshipment or intermodally using containers, swap-bodies or other transport units. Packaging, labeling, stowage and securing deficiencies can generally only be established during dispatch by spot checks. Since minor carelessness may cause serious losses, expert packing and securing are essential for loss-free carriage.

This handbook pays particular attention to negligence with regard to dispatch, which may result in losses and/or (could) form the basis of compensation payments. It has as its central theme issues relating to transport legislation, some of which will be explained and commented on in more detail. The fundamental rules to which reference will frequently be made are contained in

CTU packing guidelines
Guidelines for the packing of cargoes, other than bulk cargoes, into or onto cargo transport units (CTUs) applicable to transport operations by all surface and water modes of transport

17th February 1999
These guidelines replace the revised container packing guidelines which previously applied.

The abbreviation CTU stands for "**C**argo **T**ransport **U**nit" and has the same meaning as the expression "**I**ntermodal **T**ransport **U**nit"/"ITU").

Empty containers at a sea port

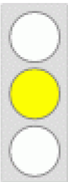
The preamble of the CTU packing guidelines points out that the use of containers, swap-bodies, vehicles or other CTUs substantially reduces the physical hazards to which cargoes are exposed.

Inadequately secured cargo on a flatrack, loaded on a roll trailer

However, they also emphasize that improper or careless packing of cargoes into or onto CTUs or improper cargo securing may cause accidents with involving personal injury during handling or transport of CTUs.

Damage caused to several containers by inadequate cargo securing

It is also pointed out that considerable damage may additionally be caused to the cargo or CTU.



Container packer adding the finishing touches

It is also stressed that the person who packs and secures the cargo is often the last person able to look inside a CTU before it is opened by the receiver at its destination. The preamble actually states:

- *drivers of road vehicles and other road users if the CTU is transported by road;*
- *railroad employees and others, if the CTU is carried by rail;*
- *crews of inland waterway vessels, if the CTU is carried on inland waterways;*
- *handling staff at inland terminals when the CTU is transferred from one means of transport to another;*
- *dock workers when the CTU is loaded and discharged;*
- *ships' crews, who often accompany the CTU under the most severe transport conditions;*
- *those who unpack the CTU.*

All persons, such as the above and passengers, may be at risk from a poorly packed container, swap-body or vehicle, particularly one which is carrying dangerous cargoes.

If containers have been closed with seals and locked, it is impossible for road vehicle drivers to check how well they have been packed and secured. Even if the transport units are freely accessible, it would still only be possible, for the most part, to inspect the cargo in the door area of box containers.

Truck combination with (safely packed) hazardous materials containers

Improperly packed containers could reduce the safety of road vehicles, e.g. due to weights shifting within the container, and encourage vehicles to overturn. Containers transported on trailers constitute a particular hazard if they are poorly packed and the cargo is inadequately secured.

Switchmen and other railroad employees are not responsible for checking that CTUs have been properly packed. Their inspection duties may extend to the proper securing of CTUs on freight cars, but not to the situation inside locked CTUs. If deficiencies are detected in open CTUs, a responsible employee is sure to intervene.

Rail vehicle with container during switching

Poorly packed and inadequately secured cargoes may put not only the switchmen but also rail passengers and other innocent parties at risk.

Unsecured cargoes can put people's lives at risk.

Poorly secured cargoes have frequently been known to smash through the end walls of a CTU in the event of a switching impact or even through the side walls during carriage by rail.

Containers on an inland waterway vessel

Naturally, the crews of inland waterway vessels cannot be expected to inspect the CTUs delivered to them for secure packing.

Transfer of a container

Cargo handling crews at inland terminals are put at risk by poorly packed, inadequately secured CTU cargoes, if they have to transfer them from one means of transport to another, as are dock workers when loading and discharging the CTU.

Loading and discharging operations at the sea port

As far as marine transport is concerned, the ship's command does not have any possibility, on a day to day basis, of influencing how CTUs are packed or how cargoes are secured in them.

Captain of a container ship with visitors on the bridge

In the early days of container shipping, it was common practice for the cargo officer to carry out at least occasional spot checks at the ports on the containers delivered for shipment. Today, due to high cargo volumes, short laytimes in port and reduced crewing levels, this is possible only very occasionally. The long-established practice of having containers checked and inspected by experts employed by the shipping companies or loss adjusters instructed by the carriers has also mostly been abandoned for cost reasons. These days, containers are only occasionally inspected by experts before loading onto the ship.

Water police inspecting a trailer to be carried by ferry

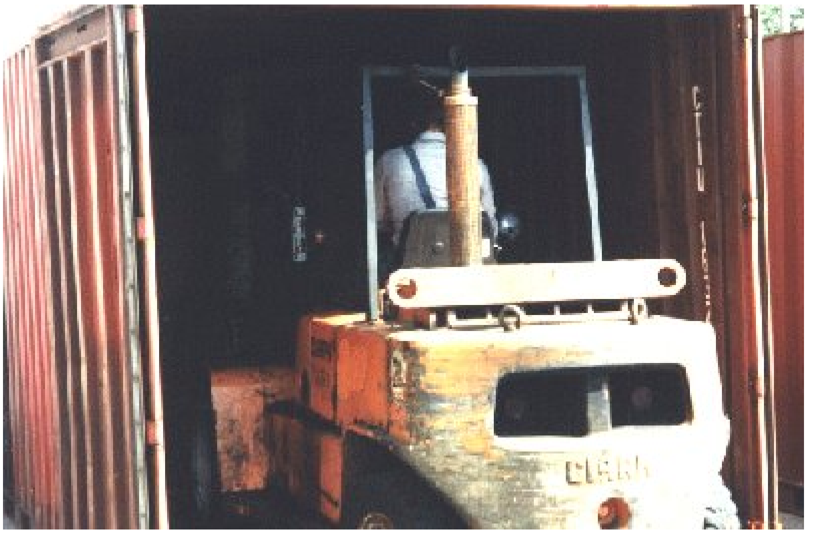
Occasionally, authorities such as the water police carry out spot checks on CTUs carrying hazardous materials.

The results of such inspections are shocking. Around 70% of containers, swap-bodies, semitrailers and other "cargo transport units" reveal clear deficiencies.

From a legal standpoint, an inspection by the ship's command is unnecessary, since the people who pack a container are responsible for ensuring that all regulations are observed. In the case of containers carrying hazardous materials, such compliance must even be confirmed by a signature on the container packing certificate. Accordingly, in the case of FCL/FCL and FCL/LCL containers, the shipper is usually responsible. The bill of lading documents this in the "shipper's load, stowage and count" clause. In the case of LCL/FCL and LCL/LCL containers, those responsible are those instructed to pack. With regard to legal liability, they bear the consequences of any deficiencies or omissions, insofar as these are not caused by the customer, for example because the latter fails to pay for necessary work to be carried out or for securing or has only very specifically defined work carried out. If people or the environment are harmed by deficient container packing, those responsible may be prosecuted. The potential for risk is particularly great when packing hazardous materials.

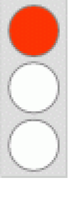
Theoretically, it is only possible for the crew of a ship to inspect cargo securing where "open" CTUs are used, such as flatracks, platforms etc., and then only when the cargo is not additionally covered by tarpaulin or otherwise hidden from view.

Those who unpack a CTU are the last people in the transport chain who may be put at risk by packaging deficiencies, poor packing and inadequate cargo securing.



Forklift truck driver stripping a container

The CTU packing guidelines do not mention the danger to individuals who inspect CTUs in the course of their work, such as police, loss adjusters and cargo inspectors.



Motorway police inspecting containers

The container (picture to the right) is packed with hazardous materials. This should have been packed in the door area, but instead was "hidden" under other items of cargo and could not be found.

Without at this point going into individual paragraphs, articles or points of regulations, laws or guidelines, it should be noted that with this type of transport too it is the shipper's duty to ensure proper packing and securing.

Poorly packed, inadequately secured container loads may also put innocent third-parties at risk if shifting items of cargo smash through the container walls or cause a vehicle carrying the container to overturn.

Inadequately secured container load

Normally, a CTU trucker cannot be held liable for losses arising due to improper packing of containers, swap-bodies, semitrailers etc., if the latter are closed with seals and are loaded in operationally safe manner, which is the case if the vehicle is roadworthy and working safely. A trucker's contract of carriage usually applies only to transport of the CTU. His duty to load the CTU in operationally safe manner is fulfilled if the appropriate total weights and axle loads are complied with, appropriate locking of the CTU is ensured and hitching is performed correctly.

If a vehicle is sealed, the trucker does not have any way of influencing, supervising or even checking packing and securing of the load. Losses due to such deficiencies, or even to packaging deficiencies, cannot therefore lie within his area of responsibility, but instead lie squarely with the shipper.

If truckers notice obvious deficiencies when they take delivery of CTUs or later due to the driving behavior of their vehicle, they must respond accordingly, however. It is advisable to ask the shipper for information or instructions.

In the case of unsealed vehicles, an internal visual inspection is advisable. Any gross errors may then be discovered. In practice such inspections are hardly ever performed, but this may make the driver partly responsible.

The shipper must always ensure that cargoes are loaded and secured in such a manner as to be safe for transport, as he is not only liable for damage to the cargo but also for damage to the vehicle or injury to third-parties resulting from dereliction of his duty.

The following is stated in § 22 of the German road traffic code, para. 1:

> *(1) The load, together with clamping chains, gear and other loading equipment, must be stowed so as to be safe during transport and be secured especially so as to prevent it from falling off and from making avoidable noise.*

This paragraph is worded very generally and does not name any particular target individual or group. It must therefore be adhered to by all those responsible for loading road vehicles.

2 Causes of damage/loss during transport

Introductory remarks

There are undoubtedly many companies in which responsible, quality-conscious staff plan and devise optimum transit procedures so that the goods to be shipped reach the receiver having suffered the least possible damage. In such companies, prevention of damage is a priority since it is common knowledge that economic success is to a great extent dependent upon customer satisfaction. Considerable effort is taken to avoid shipping damage or to restrict the extent of such damage.

But what about those personnel who don't care as much about preventing damage? Virtually inevitably, their actions or omissions cause damage and accidents.

Human failure as a cause of damage

It's not the ship's management or crew who have fallen short here, but those who were responsible for packing some of the containers. Nothing has happened to properly packed and secured containers, while poorly packed containers with inadequately secured cargoes have been destroyed.

This Container Handbook only occasionally takes a look at spectacular incidents of damage and instead primarily focuses on the numerous small and medium-sized cases of carelessness in shipping which are responsible for the majority of losses as they rapidly add up to huge sums of money.

Human failure - from another perspective

Only poorly packed containers with inadequately secured cargoes have been destroyed. Even the vehicles labeled 1 and 2, which were not ideally secured, have withstood the effects of the rough seas.

Analysis of shipping losses frequently focuses on technical issues and takes human shortcomings more or less as read. Such an approach is mistaken, ultimately meaning that the necessary staff training is not provided because it is not regarded as sufficiently important, an attitude shared by the decision-makers.

Damaged containers should not be used.

Insufficient knowledge and inadequate skills on the part of many of those involved in cargo shipping are the root causes of subsequent losses. Errors in the planning and execution of transport operations are for the most part due to human failure.

Inadequate training promotes damage.

Poor understanding on the part of many of those in charge about the complex interrelationships involved in the provision of transportation services together with what is in most cases a very low level of training among the personnel involved with the physical handling of cargoes conspire to cost the world's economy billions every year.

Insufficient knowledge and inadequate skills on the part of very many of those involved in cargo shipping are the root causes of subsequent losses.

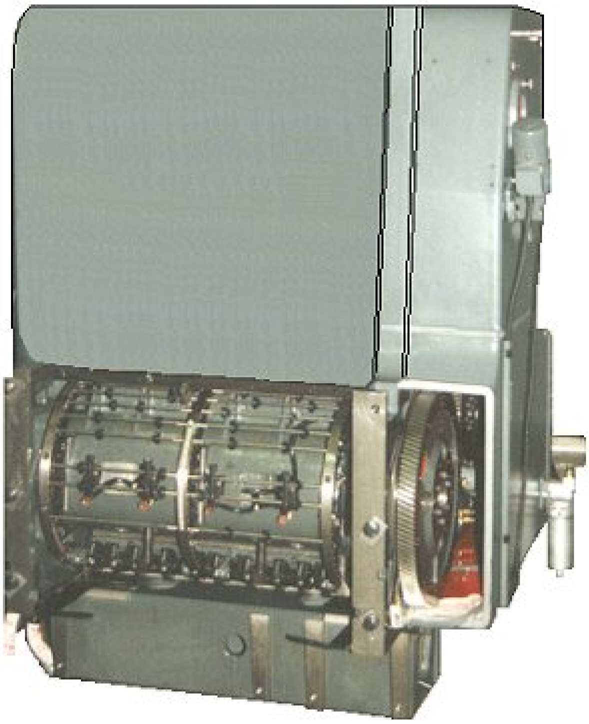
Basic errors are sometimes made as early as during design and production of the goods which are ultimately to be shipped. While this area will be addressed separately in the section "Packaging errors and deficiencies", some explanatory examples are given below.

Non-regulation dangerous cargo unit

Even trained packers would have difficulty packing this cargo unit safely into a container, in fact it would be impossible without additional labor and materials costs.

Non-regulation dangerous cargo unit

Given the differing heights of the drums, this cargo unit is even more difficult to pack into a container.



Machine without securing means: not fit for shipping

Designers not only have to take account of a machine's subsequent function, but also of the fact that it must first be transported to where it will be used and installed there without suffering damage. Every machine should have slinging and lashing points so that it can be handled and secured without problem.

Earth borer without securing means: not fit for shipping

This earth borer has no lashing points. In such cases, securing means are generally attached arbitrarily to components which are not suitable for this purpose. The absence of lashing points is particularly disadvantageous since this machine will be used at many different sites. Every time the machine is moved, more effort will be required for securing, so increasing the shipping risk, which is why:

Attention must be paid to lashing points for easy transport securing from the design stage.

2.1 Loss prevention through training

The section "Scope" of the CTU packing guidelines contains an important statement:

These Guidelines, which are not all-inclusive, are essential to the safe packing of CTUs by those responsible for the packing and securing of the cargo and by those whose task it is to train people to pack such units. Training is essential if safety standards are to be maintained.

According to section 7.2 of the CTU packing guidelines, this is a management responsibility:

Management should ensure that all personnel involved in the packing of cargo in CTUs or in the supervision thereof are adequately trained and appropriately qualified, commensurate with their responsibilities within their organization.

Section 7.3 states the following requirement for personnel:

All persons engaged in the transport or packing of cargo in CTUs should receive training on the safe packing of cargo in CTUs, commensurate with their responsibilities.

Section 7.4 relates to training, the various subsections providing as follows:

7.4.1 General awareness/familiarization training:

All persons should receive training on the safe transport and packing of cargo, commensurate with their duties. The training should be designed to provide an appreciation of the consequences of badly packed and secured cargo in CTUs, the legal requirements, the magnitude of forces which may act on cargo during road, rail and sea transport, as well as basic principles of packing and securing of cargoes in CTUs.

7.4.2 Function-specific training:

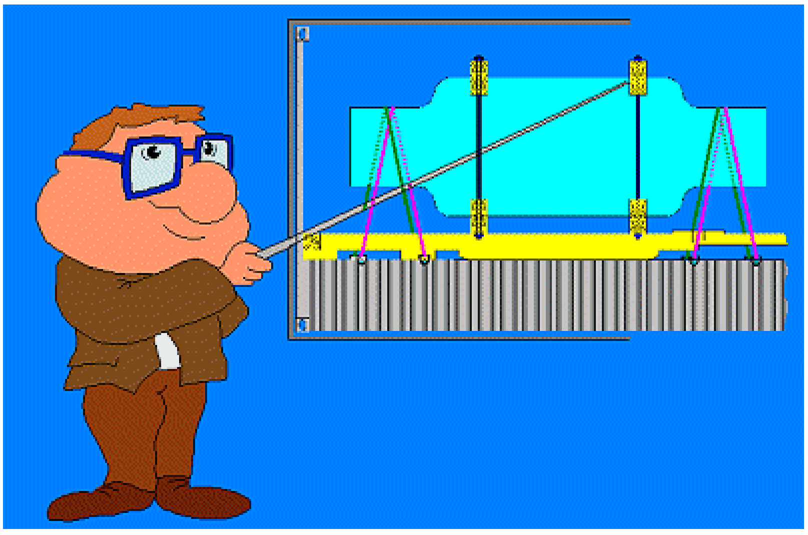
All persons should receive detailed training concerning specific requirements for the transport and packing of cargo in CTUs which are applicable to the functions that they perform.

7.4.3 Verification:

The adequacy of the knowledge of any person to be employed in work involving the packing of cargo in CTUs should be verified or appropriate training provided. This should be supplemented by periodic training, as deemed appropriate by the regulatory authority.

7.5 Recommended course syllabus - overview:

The adequacy of the knowledge of any persons to be employed in work involving the packing of cargoes in CTUs should be verified, in the absence of which appropriate training is considered essential and should be provided. The function-specific training should be commensurate with the duties required to be performed by an individual in the packing and securing of cargo in CTUs. Topics for consideration, to be included in the training as appropriate, are given in Annex 6.



Annex 6

Topics to be included in a training programme for the packing and securing of cargoes in cargo transport units (CTUs)

1 Consequences of badly packed and secured cargo

1.1 Injuries to persons and damage to the environment

1.2 Damage to ships and CTUs

1.3 Damage to cargo

1.4 Economic consequences

Many may still remember the case of the French container ship "Sherbro" which lost a number of containers overboard in the English Channel. As a result, hundreds of thousands of plastic sachets containing the pesticide Apron plus entered the sea and were subsequently washed up on the coasts of France, the Netherlands and Germany.

Injuries to persons and damage to the environment may be the result.

Damage to ships and CTUs

Damage to cargo

Economic consequences

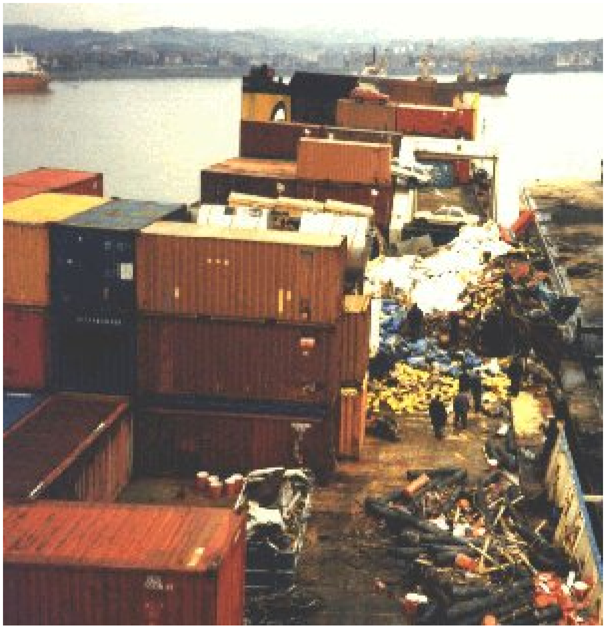
13 Packing and securing of dangerous cargoes

- 13.1 Regulations for the transport of dangerous cargoes
- 13.2 Definitions
- 13.3 Packing regulations
- 13.4 Packing, separation and securing
- 13.5 Labeling and placarding
- 13.6 Information transfer when transporting dangerous cargoes
- 13.7 Liabilities

Comprehensive and regularly recurring training sessions are necessary in order to ensure sufficient familiarity. On request, the German Insurance Association (GDV e.V.) can supply the names of training organizations which carry out or assist with internal and external training.

2.2 Damage - risks - countermeasures

The cargo in this container had obviously not been sufficiently secured. As a result, the container was destroyed from the inside.

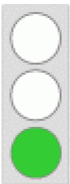


Considerable damage to the cargo and the ship itself due to inadequate cargo securing

Cargo from the destroyed containers on deck

It is essential to avoid even the smallest gaps.

A cargo unit (at the top) has been packed with gaps on both sides. Moreover, the cargo unit was inappropriately unitized.



Perfect example of how to fill gaps (to the left)

2.3 Shipping stresses - general information

Shipping stresses must in general be divided into two main groups:

- avoidable shipping stresses
- unavoidable shipping stresses

Avoidable shipping stresses are attributable to human shortcomings. Incidents of damage often occur because the cargo has been inadequately packed, stowed or secured or because equipment has been used incorrectly. The CTU packing guidelines also attempt to counter these human causes by providing in Annex 6 a list of topics to be included in a training program for the packing and securing of cargoes in cargo transport units (CTUs), which requires in point 3 that packers be instructed as to the forces acting on the cargo during transport, whether by road, rail or sea. This requirement stated in the CTU packing guidelines deserves strong support as observation of day-to-day practice reveals a frightening lack of knowledge in precisely this area.

Unavoidable shipping stresses are determined by the nature of the transport operation and lie largely outside the sphere of human influence.

Very large numbers of incidents of damage are attributable to the fact that many of those involved in shipping are unaware of shipping stresses or assess them incorrectly. This ought not to be the case as information of this kind is available from many different sources. Section 1 "General conditions" in the CTU packing guidelines provides important information about how cargoes are affected particularly during voyages. Information about road, rail and inland waterway transport and about cargo handling is also provided. In addition, the German vehicular accident prevention regulations (BGV D 29) and VDI guidelines also state values for road transport. Values for the stresses arising in rail transport may be obtained from publications from the German railroad company Deutsche Bahn AG or the UIC.

It is not without reason that the CTU packing guidelines contain the following important statement in the point Scope:

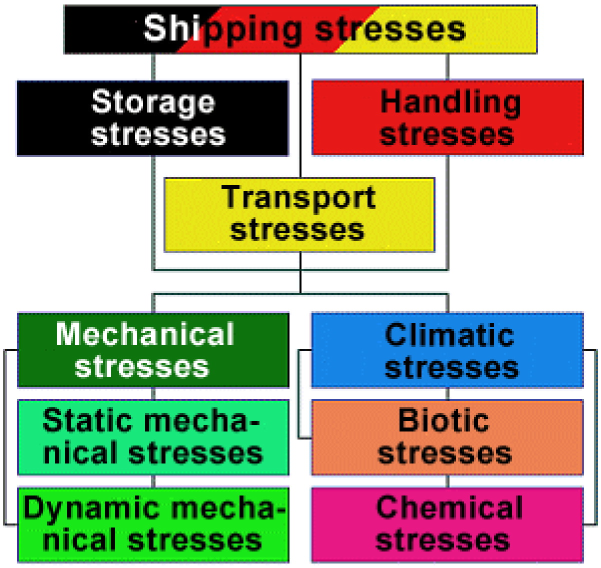
> *These Guidelines are not intended to conflict with, or to replace or supersede, any existing regulations or recommendations which may concern the carriage of cargo in CTUs.*

In other words, there is no intention to reinvent the wheel in the CTU packing guidelines; much of the information they provide has already been published in other guidelines and specialist publications.

> ***Carriage** denotes the movement of cargo using one or more modes of transport.*

The terms "carriage" and "shipping" are superordinate terms covering storage, handling and transport and any associated operations.

The stresses arising during shipping may thus be summarized as shown below:



Overview of shipping stresses

It is extremely difficult to put exact values on storage, handling and transport stresses because they are determined by many different parameters. In addition to the stresses shown in the overview, other factors of course also play a part, such as the means of transport used, the selected routes, the nature of the roads and railroads or the particular weather conditions prevailing during maritime transport.

Protection from shipping damage may be provided with regard to economic viability without consequently being less effective. Effective and economic protective measures can be implemented if enough is known about the stresses to which the cargo is exposed during transport.

As experience has shown and measurements have confirmed, the shipping stresses of different modes of transport differ markedly. Nevertheless, there are similarities and common features which should be taken into account in the following explanations.

However, it is not feasible to generalize about transport operations, each one will be somewhat different and will also be affected by randomly occurring factors. The better trained are those involved, the better will they be able assess the transport risks and take effective action to counter them. Training and quality control are two key concepts which should play a central part in cargo securing.

2.3.1 Static mechanical shipping stresses

Static mechanical stresses primarily cause damage due to harmful levels of pressure. In the transport sector, cargoes are often thought of only as light or heavy, so neglecting the fact that these are relative terms which it is highly advisable to verify.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

Stated using conventional abbreviations:

(p for pressure, F for force and A for area)

$$p = \frac{F}{A}$$

The official SI unit of calculation is the pascal, which is a pressure of one newton per square meter (Pa = N/m²). This very small unit is rarely used for practical calculations. Atmospheric pressures are calculated in hectopascals (hPa), while tire pressures, stacking pressures etc. are usually calculated in kilopascals (kPa) or megapascals (MPa).

In the pressure formula, force is above the fraction line, which means that, given an identical area, a larger force will result in a larger pressure. Area is beneath the fraction line, i.e. the smaller the area, the greater the pressure and vice versa.

If the maximum permitted stack pressure in containers is not known, it may relatively easily be determined. Point 3.1.7 of the CTU packing guidelines provides an indirect indication of how this is done:

> *Stowage planning should take account of the fact that CTUs are generally designed and handled assuming the cargo to be evenly distributed over the entire floor area. Where substantial deviations from uniform packing occur, special advice for preferred packing should be sought.*

The permitted payload in a container is the net mass which is obtained when the tare weight is deducted from the maximum gross mass. The following worked examples are for two different 20' and 40' containers:

Payload in kilograms	Force in newtons	Internal length in meters	Internal width in meters	Pressure in pascals	Pressure in kilopascals
18,370	180,209.70	5935	2370	12,811.77	12.81
21,780	213,661.80	5895	2393	15,146.08	15.15
26,700	261,927.00	12,033	2352	9,254.84	9.25
29,650	290,866.50	12,069	2350	10,255.45	10.26

Example calculation of permitted stack pressure in containers

In the literature, values of 14 kN/m² for 20' containers and of 10 kN/m² for 40' containers are frequently stated as maximum floor loading values. However, as has been shown, this value varies from container to container and may easily be calculated. The maximum stack pressure in a container would be the same as the maximum container floor loading value if the container were packed absolutely evenly.

Official pressure units are only very rarely used for calculations in the transport sector. Since it is masses which are handled, pressure is often assumed to be the product of dividing mass by area:

Instead of the official units, units such as kg/ cm², kg/m², metric tons/m² or the English-speaking world's psi (pounds per square inch) are used. While, strictly speaking, this is incorrect, such units are widely used in practice and are more readily comprehensible to many of the personnel involved. The following relations apply when converting such units into the official units and vice versa.

- Hectopascals (hPa) correspond to the old unit millibar (mbar).
- One bar corresponds to 100 kPa or 0.1 MPa.
- Kilogram/square centimeter (kg/cm²) roughly corresponds to one bar or 100 kPa or 0.1 MPa.
- One kilogram/square centimeter corresponds to 10 metric tons/m²
- One kilopascal (kPa) = 1000 N/m² and corresponds to 100 kg/m² or 0.1 metric tons/m².
- One kilogram/square centimeter roughly corresponds to 14 lb/square inch (psi).

A forklift truck tire pumped up to a pressure of 8.5 bar accordingly has a pressure of 85 kPa, 0.085 MPa or, roughly, 8.5 kg/cm² or 85 metric tons/m². In the English-speaking world, the tire is at a pressure of 119 psi.

The stacking crush pressure is the pressure exerted by an item of cargo on underlying items of cargo or components.

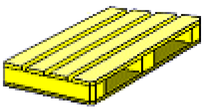
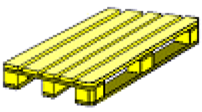
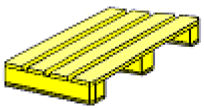
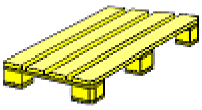
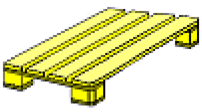
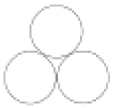
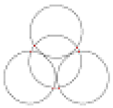
Pallet structure	Force in newtons	Area of base in m²	Crush pressure kN/m² = kPa
	9,810	1000	9.81
	9,810	0.432	22.71
	9,810	0.288	34.06
	9,810	0.0864	113.54
	9,810	0.0576	170.31

Table: Crush pressures for different pallets

Crush pressures are significantly higher for some pressboard pallets and similar types. Unless appropriate measures are taken to distribute the pressure, it is not possible to guarantee that transport will proceed without damage.

Elevated stacking crush pressures due to small contact areas

Extremely high pressures may occur if buckets, pails, barrels and similar cargoes are packed without an intermediate layer. For example, if a barrel of a mass of 183.5 kg and a total area of the barrel rim of 90 cm² is placed on the floor, a pressure of 200 kN is generated. Assuming the barrel rim to have a width of 0.5 cm, offset stowage of another barrel on top will result in a contact area of 0.00015 m², generating a pressure of 12,000 kPa.

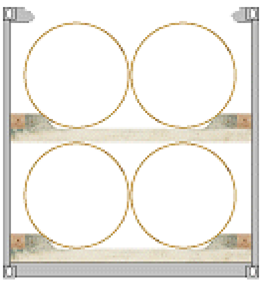
Type of packing / contact areas		Force [N]	Area [m²]	Pressure [kPa]
		1,800	0.0090	200
		1,800	6 x 0.5 cm x 0.5 cm = 1.5 cm 0.00015 m²	12,000

The only way forwarding personnel can prevent damage due to static mechanical stresses is by taking steps to distribute the pressure, as it is not possible to modify the shipping packages themselves or to change the masses involved. However, many warehouses and packing centers do not hold stocks of appropriate materials in the form of walking boards, hardboard, wooden dunnage etc. Appropriate intermediate layers are often not used due to ignorance, for reasons of false economy or other motives.

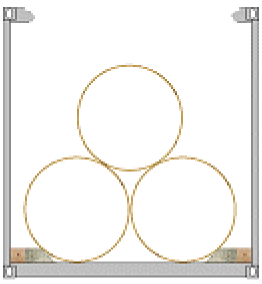
It is essential to take the nature of the shipping packages into account. A skilled appraisal of the external appearance, such as the base of cases, cargo units and pallets, can provide valuable information as to how to load them. Efficient handling methods using lifting gear or ground conveyors usually require the use of beams or squared lumber beneath or between the items of cargo and such use can produce damaging levels of pressure.

Even strapping packages may cause damage due to excessive pressure if edge protectors are not used to distribute the pressure in order to offset the weakness of the packages.

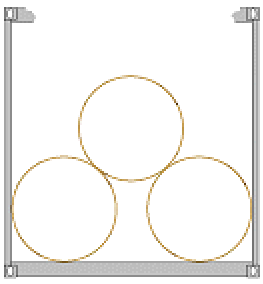
Very high pressures are generated by narrow or point bearing areas. Negative effects are magnified by multiple tiers or the angles of rest which arise, for example, when stowing pipes, rolls or similar cargoes.



Packing in tiers



Cantline 1

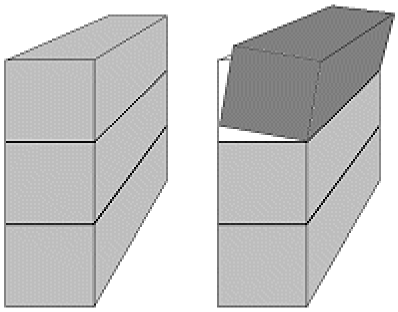


Cantline 2

Packing in tiers generates extremely high pressures, as the pipes are only bearing on narrow strips corresponding to the edge lengths of the lumber. The resultant stack pressures are distinctly higher than in either of the two cantline stows. Due to the greater angles of rest or spread, cantline stow 2 generates greater forces than cantline stow 1. Further explanations in this respect may be found in the section, "Basic stowage methods".

The crush pressures bearing down on underlying layers of packages or the container floor is increased by the ship's motion. It is often forgotten that pressure does not only act downwards from above due to the force of gravity, but may also act laterally due to dynamic stresses. In this case, the packages are pressed against one another or the container walls. This pressure and in particular slipping and subsequent collision of inadequately secured packages may result in damage.

Very few packers anticipate "home-grown" static mechanical stresses due to inadequate cargo securing, but such stresses are predictable: if cargo stacks can move, critical and dangerously high pressures may arise as tipping occurs due to the resultant very small contact area.



"Home-grown" static mechanical stresses

The reduction in contact area with a simultaneous increase in pressure may cause the edges of the packages to cave in, resulting in damage to the shipping packages and collapse of the stack. In particularly unfavorable cases, this may result in the loss of whole batches or even of the container.

The actual tipping, collision or collapse of packages will be addressed in the dynamic mechanical shipping stresses section.

2.3.2 Dynamic mechanical shipping stresses

In relation to dynamic stresses, a primary distinction is drawn between vibration and jolting. In physical terms, the two phenomena are similar, but the distinction is made because they differ in their effects on packages and means of transport.

Vibration comprises periodic oscillations which generally occur in large numbers, such as vehicle or engine vibration, movement of ship in rough seas etc.

Jolting comprises occasional events, as may be observed on impact, dropping or tipping. Bumping, kicking or switching impacts are all words which paint a sufficiently clear picture.

The absolute magnitude of both types of stress is measured from their amplitude. For vibration, the second important parameter is frequency, i.e. the number of periodically repeating oscillations within a specific period [cycles/second]. For jolting, pulse duration and frequency are the other determining factors in addition to amplitude.

Dynamic mechanical shipping stresses are accordingly primarily caused by acceleration arising from changes in direction or speed. Acceleration values are particularly high if these changes occur very rapidly. The formulae clarify the relationship:

$$\text{Linear acceleration} = \frac{\text{Change in speed}}{\text{Time}}$$

since

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

, it follows that linear acceleration may be calculated from the following formula:

$$\text{Linear acceleration} = \frac{\text{Distance}}{\text{Time x Time}} = \frac{\text{Distance}}{\text{Time}^2}$$

$$a = \frac{\Delta v}{\Delta t} = \frac{s}{t \times t} = \frac{s}{t^2} \left[\frac{m}{s^2} \text{ or } \frac{km/h}{s} \right]$$

If a car accelerates from 0 km/h to 108 km/h in 12 seconds, its speed has changed by 9 km/h or 2.5 m/s each second.

Its acceleration, a, is thus 9 km/h/s or, stated in other terms:
2.5 m/s·s or 2.5 m/s If a truck traveling at a speed of 90 km/h takes five seconds to come to a standstill, it is decelerating at 18 km/h per second or 5 m/s per second. This is precisely the braking deceleration of 5 m/s^2 specified in the German road traffic licensing regulations (StVZO) and German accident prevention regulations.

A ship which, while pitching in a heavy sea, suffers a loss of speed from 21 knots to 9.3 knots within 2 seconds undergoes negative acceleration of
-11.7 kn/2 s = -5.85 kn/s = -10.834 km/h/s = -3 m/s^2 and is thus decelerated.

Acceleration arising from a change in direction may be calculated in accordance with the following formula:

$$\text{Radial acceleration} = \frac{\text{Speed}^2}{\text{Curve radius}}$$

If a road vehicle takes a tight curve with a curve radius of 20 m at a speed of 36 km/h, which corresponds to 10 m/s, it undergoes radial acceleration of 5 m/s^2.

Driving through potholes also causes radial acceleration because there is a change in direction from the horizontal to the vertical and back again. In vehicles with poor shock absorption, this causes considerable acceleration as the curve radii are very small and the speeds at which they are driven through are relatively high. In this case, only the suspension and other design parameters protect the vehicle and its load from severe damage. In roll trailers without suspension, rough ground in the terminal may result in high levels of acceleration and consequent damage to the cargo. It is a relatively frequent occurrence for shipping packages to fall off the trailers during such transport operations within cargo handling facilities.

The action of gravity subjects any object on the earth to downwards acceleration, which is known as acceleration due to gravity. The value of this acceleration is constant. Acceleration due to gravity, rounded to two decimal places, is 9.81 m/s^2 and is designated 1 g. For rough calculations, 1 g may also be assumed to have a value of 10 m/s^2.

In order to appreciate quite what an acceleration of 1 g means, imagine a road vehicle accelerating from 0 km/h to just about 106 km/h in 3 seconds. The calculation is as follows:

$$a=\frac{\Delta v}{\Delta t}=\frac{105.948\,\cancel{km}\cdot 1000\,m}{3\,s\;\;\cancel{h}}\;\frac{\cancel{h}}{\cancel{km}\;\;3600\,s}=9.81\,\frac{m}{s^2}$$

If the magnitude of an acceleration is known, the force it applies to a mass may be calculated from Newton's second law of motion:

$$\text{Force} = \text{Mass} \cdot \text{Acceleration}$$

The formulae are conventionally written:

$$F = m \cdot a \quad [N = kg \cdot m/s^2] \quad \text{or} \quad [kN = t \cdot m/s^2]$$

$$F = m \cdot g \quad (g = 9.81\ m/s^2)$$

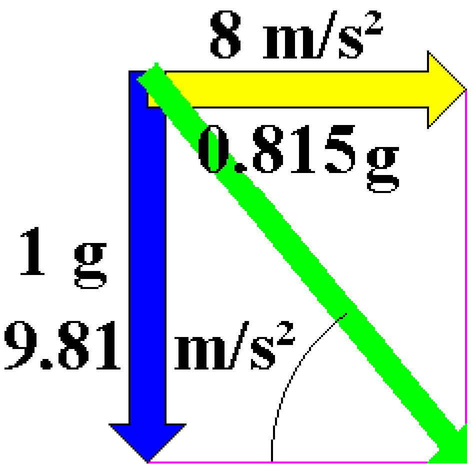
On earth, force and weight are physically identical. As a result of acceleration due to gravity, an object of a mass of 100 kg exerts a force of F = 100 kg x 9.81 m/s^2 = 981 N on whatever is supporting it. Stated in other units, this force amounts to 98.1 daN (decanewtons) or 0.981 kN (kilonewtons).

Weight-force should accordingly be taken to mean the force with which an object is attracted by the earth's gravity. This force always acts perpendicularly downwards. The formula used is as above, but replacing the general abbreviation F for Force with G.

$$G = m \cdot a \quad [N = kN \cdot m/s^2] \quad \text{or} \quad [kN = t \cdot m/s^2]$$

Some publications, such as for example the VDI Guidelines, mention normal force and the abbreviation F is provided with the index N, giving FN = normal force.

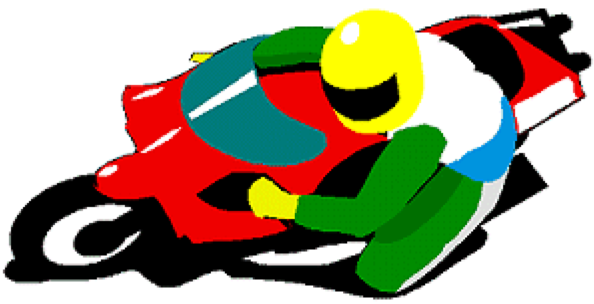
Force and acceleration are vector quantities, i.e. quantities in which both magnitude and direction must be stated. Acceleration due to gravity g, however, is always in the same direction as weight.



A motorcycle rider traveling around a corner with a radius of 50 m at 72 km/h will experience radial acceleration of 8 m/s^2 ($a_r = v^2/t$ = 20 m/s x 20 m/s / 50 m = 8 m/s^2).

Composition of forces in a parallelogram of forces

The blue vector of acceleration due to gravity of 1 g or 9.81 m/s^2 acts perpendicularly downwards, the yellow vector of radial acceleration of 8 m/s^2 acts horizontally in the direction of the curve and corresponds to 81.5% of acceleration due to gravity (0.815 g). The green vector is the resultant acceleration of 12.658 m/s^2. The direction of the resultant vector is also described as the apparent vertical.



A motorcycle rider must lean into the curve by 39.2°, relative to the vertical, in order to offset this force. His motorcycle will then be at an angle of 50.8° to the horizontal (tan \alpha; = 9.81 m/s^2 ÷ 8 m/s^2 = 1.22625) and he will be pressed down towards the ground with approx. 1.3 times his normal force (12.658 m/s^2 ÷ 9.81 m/s^2).

If, instead of being stated in m/s^2, acceleration values are given in fractions or multiples of acceleration due to gravity (g), the forces may be determined with sufficient accuracy directly in decanewtons (daN), if mass is stated in kilograms (kg).

If the mass is located within a frame of reference under acceleration, the vector exhibits an inertia force acting on the mass in the opposite direction to the acceleration. An example of this is the automobile driver who, on accelerating, is pressed back into his seat (positive acceleration and negative inertia force) or, on braking, is pulled forward (negative acceleration and positive inertia force).

Friction forces are passive forces, which come into play when objects on a substrate are to be set in motion by forces (static friction) or are to be kept in motion (sliding friction and rolling friction). Static friction also comes into play when the direction of motion of an object (already subject to sliding or rolling friction) is changed. An automobile cornering is a good example, as all that keeps the vehicle on its desired path is the sufficient static friction of the tires (in reality, the phenomena at play are more complex than shown here). Friction forces counteract incident forces. The following formulae may be used to calculate the size of friction forces.

Static friction = Normal force perpendicular to sliding surface · Friction coefficient for static friction

$$f_0 = n \cdot \mu_0$$

Sliding friction = Normal force perpendicular to sliding surface · Friction coefficient for sliding friction

$$f = n \cdot \mu$$

The normal force perpendicular to the sliding surface may be stated in N, daN, kN or similar units of force. Since the various coefficients of friction are dimensionless, the determined friction force has the same calculation dimension as for the normal force perpendicular to the sliding surface.

Since friction is of great significance to cargo securing, more detailed explanations will be provided in another section.

Vibration and jolting of the vehicles and equipment used, together with the fundamental and resonant vibration of goods, packaging and cushioning material together largely define the risk of damage to which the goods are exposed during carriage. The magnitude of the **pulses**, i.e. the duration of forces or velocity of masses, is of vital significance in this connection.

Note: If sensitive goods are to be packaged and carried without suffering damage, it is essential to be aware not only of the frequency spectra which arise during storage, handling and transport but also of the natural frequencies of the goods being shipped, the shipping packages, cushioning material etc. In the high frequency range, extremely high acceleration values of several dozen to a few hundred g have been measured. However, due to the mass inertia of the shipping packages, such short duration impacts rarely cause damage due to inadequate cargo securing. However, the consignor must provide appropriate packaging for sensitive goods in order to mitigate such vibration. In the low frequency range, acceleration values encountered during transport and handling are of the order of some fractions of a g to several g. The longer period of action may result in shifting of the cargo and consequent mechanical damage. These low "normal values" applying to cargo securing on or in vehicles are stated by various organizations. Those involved with shipping should be aware of usual g values.

The effects of dynamic mechanical shipping stresses are frequently underestimated, despite the "normal values" being widely available or easily obtainable. The CTU packing guidelines contain various comments on this issue.

Note: The following comments may be made regarding the tables shown in section 1.9 of the CTU packing guidelines: the wording/notation is incorrect in that forces are stated in the column headings, while the level of acceleration caused by such forces is stated in the associated fields. If forces are the intended meaning, "g" as a measure of acceleration due to gravity of 9.81 m/s² ought to be replaced by "G" as a unit for the normal force. If, however, the values in the table are intended to indicate the level of acceleration, the word "forces" in the column headings ought in each case to be replaced by "acceleration". The same applies to the wording of the footnotes to the tables.

2.3.3 Mechanical stresses in maritime transport

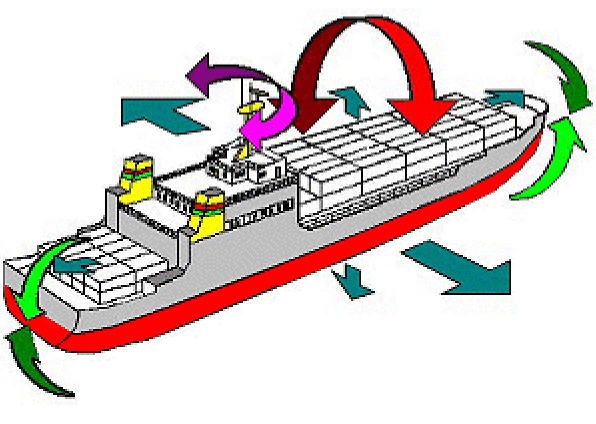
Section 1 "General conditions" in the CTU packing guidelines clearly states, for example in point 1.1:

> *Voyages are made in a variety of weather conditions which are likely to exert a combination of forces upon the ship and its cargo over a prolonged period. Such forces may arise from pitching, rolling, heaving, surging, yawing or swaying or a combination of any two or more.*

Point 1.2 continues:

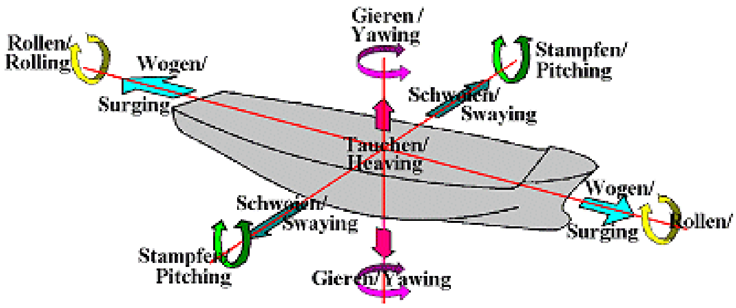
> *Packing and securing of cargo into/onto a CTU should be carried out with this in mind. It should never be assumed that the weather will be calm and the sea smooth or that securing methods used for land transport will always be adequate at sea.*

The acceleration values to be anticipated in maritime transport depend on the shape of the surface or sub-surface vessel, its beam, the position of the center of gravity and center of buoyancy and similar parameters which determine the behavior of ships at sea.



Ship movement at sea

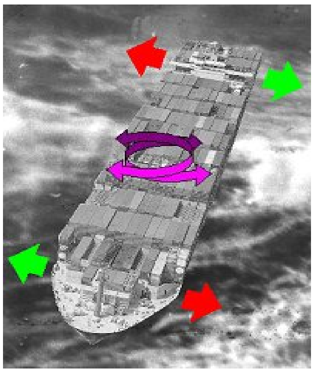
All kinds of ship movement may be divided into three types of linear motion and three types of rotational motion.



Linear motion	Rotational motion
Surging is motion along the longitudinal axis.	Rolling is motion around the longitudinal axis.
Swaying is motion along the transverse axis.	Pitching is motion around the transverse axis.
Heaving is motion along the vertical axis.	Yawing is motion around the vertical axis.

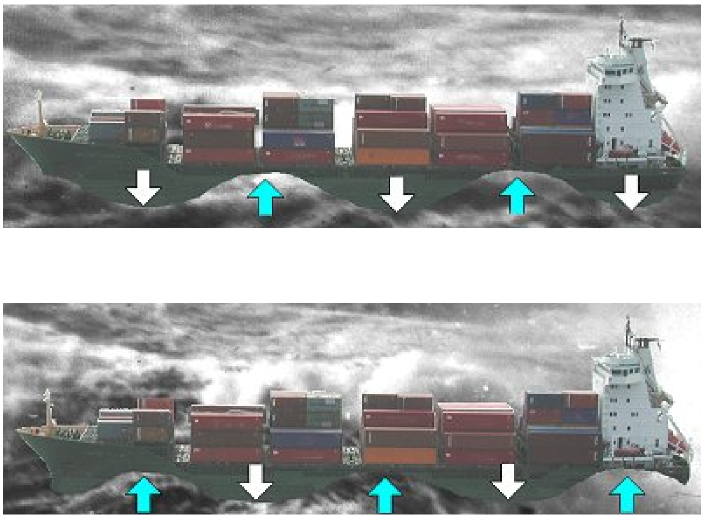
Summary of ship movement

It can in general be stated that the outwardly directed centrifugal accelerations brought about by any rotational motion are not significant. This accordingly applies to yawing, pitching and rolling.



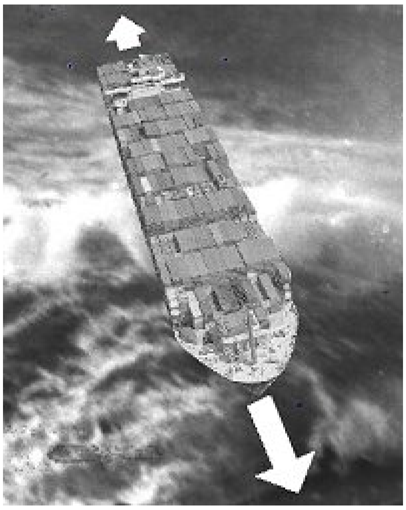
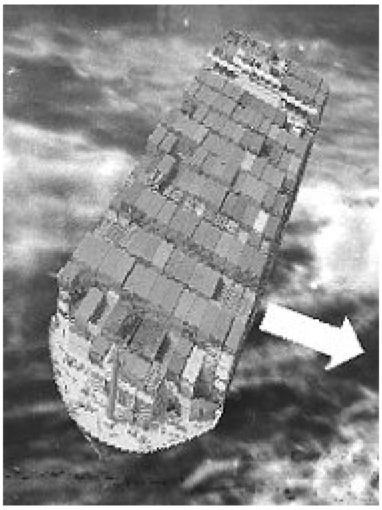
Yawing is motion around the ship's vertical axis.

Yawing involves rotation of the ship around its vertical axis. This occurs due to the impossibility of steering a ship on an absolutely straight course. Depending upon sea conditions and rudder deflection, the ship will swing around its projected course. Yawing is not a cause of shipping damage.



Heaving is motion along the ship's vertical axis.

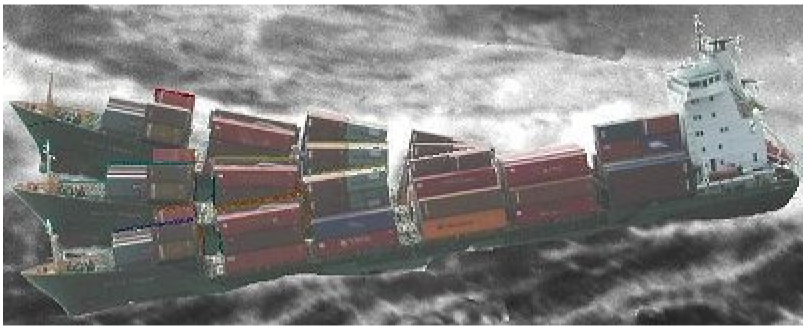
Heaving involves upward and downward acceleration of ships along their vertical axis. Only in an absolute calm are upward and downward motion at equilibrium and the ship floats at rest. Buoyancy varies as a ship travels through wave crests and troughs. If the wave troughs predominate, buoyancy falls and the ship "sinks" (top picture), while if the wave crests predominate, the ship "rises" (bottom picture). Such constant oscillation has a marked effect on the containers and their contents.

Surging is motion along the ship's longitudinal axis.

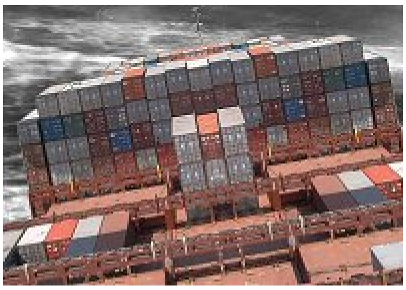
Swaying is motion along the ship's transverse axis.

In **surging** and **swaying**, the sea's motion accelerates and decelerates the ship forward and backward and side to side. Depending upon the lie of the vessel, these movements may occur in all possible axes, not merely, for example, horizontally. If a vessel's forebody is on one side of a wave crest and the afterbody on the other side, the hull may be subjected to considerable torsion forces.



Pitching is the movement of a ship around its transverse axis.

In **pitching** a ship is lifted at the bow and lowered at the stern and vice versa. Pitching angles vary with the length of vessel. In relatively short vessels they are 5° - 8° and sometimes more, while in very long vessels they are usually less than 5°. In a container ship 300 m in length with a pitching angle of 3°, a container stowed in the bay closest to the bow or stern at a distance of approx. 140 m from the pitching axis will cover a distance of 29 m within a pitching cycle, being raised 7.33 m upwards from the horizontal before descending 14.66 m downwards and finally being raised 7.33 m again and then restarting the process. During upward motion, stack pressures rise, while they fall during downward motion.

Rolling is the movement of a ship around its longitudinal axis, the rolling angle in this case being 10°.

Rolling involves side-to-side movement of the vessel. The rolling period is defined as the time taken for a full rolling oscillation from the horizontal to the left, back to horizontal then to the right and then back to horizontal. In vessels with a high righting capacity, i.e. stiff ships, rolling periods of ten seconds and below are entirely usual. Rolling angle is measured relative to the horizontal. Just in moderate seas, even very large vessels roll to an angle of 10°.

Rolling angles of 30° are not unusual in heavy weather.

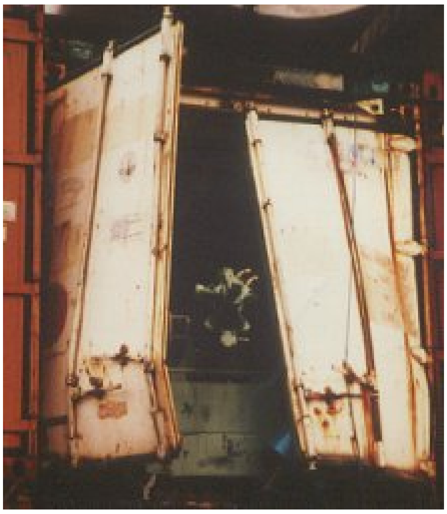
In bad weather, angles of 30° are not unusual. Even the largest container ships must be expected to roll to such angles. Stabilizers and other anti-heeling systems may help to damp ship movements. However, not all systems are usable or sufficiently effective in bad weather.

Rolling angle of 45°

On rare occasions, rolling angles may reach 45° and above. It is easy to imagine what that means for inadequately secured container cargoes.

Rolling and **pitching** of a vessel generate upward and downward acceleration forces directed tangentially to the direction of rotation, the values of which increase with distance from the rolling or pitching axis and are inversely proportional to the square of the rolling or pitching periods. At an identical distance from the axis, if the rolling or pitching period is halved, acceleration forces are quadrupled, while if the rolling or pitching period is doubled, acceleration forces are quartered. Rolling or pitching angles generate downslope forces. Steeper tilting, as occurs during rolling, promote cargo slippage. As already mentioned, the outwardly acting centrifugal accelerations generated by rotational motion are of no significance in rolling and pitching.

Overall, containers and packages may be exposed to such accelerations for very long periods when at sea. Moreover, the oscillations may be superimposed one on the other and be intensified.

Damage to containers in rolling motion, caused by inadequately secured cargo:

left: in a container stowed athwartships right: in a fore and aft stowed container

It must be emphasized that it was not the "hazards of the sea" which caused the damage, but instead inadequate securing inside the container. While such damage has indeed occurred in association with the rolling motion of the ship, the root cause is the "home-grown" acceleration forces arising from shortcomings in packing and securing.

Slamming describes the hydrodynamic impacts undergone by a ship.

Slamming is the term used to describe the hydrodynamic impacts which a ship encounters due to the up and down motion of the hull, entry into wave crests and the consequent abrupt immersion of the ship into the sea.

Vibration from the hull can be transferred to the cargo. Goods are exposed to stresses from the extremely low frequency oscillations generated by sea conditions and by higher frequency machinery and propeller vibration. Such risks can and must be avoided by using seaworthy shipping packages which are fit for purpose.

The **absolute acceleration values** encountered on board ship are not excessively high. In favorable stowage spaces, they may even be considerably lower than those encountered in land or air transport. In many cases, not even the values stated in the following Table occur. However, the frequency with which the motion occurs must definitely be borne in mind. At a rolling period of 10 s, a ship moves side to side 8640 times daily. Over several days' bad weather, the cargo will thus be exposed to alternating loads tens of thousands of times.

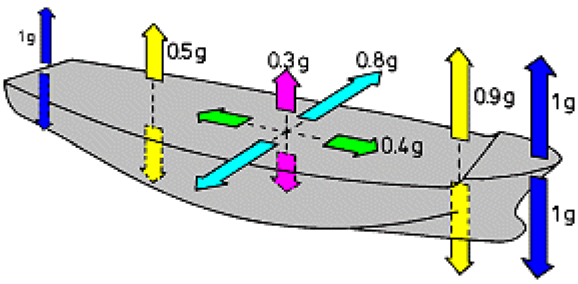
Mode of transport: ocean-going vessel	Forward acting forces	Backward acting forces	Sideways acting forces
Baltic Sea	0.3 g (b)	0.3 g (b)	0.5 g
North Sea	0.3 g (c)	0.3 g (c)	0.7 g
Unrestricted	0.4 g (d)	0.4 g (d)	0.8 g
1 g = 9.81 m/sec² The above values should be combined with static gravity force of 1.0 g acting downwards and a dynamic variation of:			
	(b)= ±0.5g	(c)= ±0.7g	(d)= ±0.8g

Extract from a Table in the CTU packing guidelines

In relation to the Table, it is stated in point 1.7 of the CTU packing guidelines that examples of accelerations are given which could arise during transport operations:

However, national legislation or recommendations may require the use of other values.

The values stated in footnotes (a), (b) and (c) in principle describe accelerations in the vertical direction. Such accelerations are particularly high in pitching and rolling movements and, in exposed positions in very bad weather, can easily reach 1 g. The CTU packing guidelines here state the maximum at 0.8 g. Vertical acceleration reduces friction forces and increases stack pressure.



Overview of acceleration forces prevailing on board a ship

Annex 13 of the CSS Code contains tables for determining acceleration forces as a function of stowage space on board, the ship's length and speed. However, these tables are not suitable for use when packing CTUs and securing cargoes in or on CTUs, specifically for the following reasons:

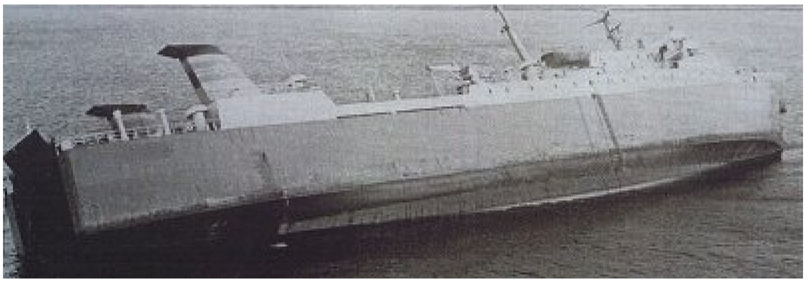
If containers, road vehicles, rail cars or the like and road trailers, roll trailers and semitrailers are loaded inland for maritime transport, their ultimate stowage space on board is unknown. The least favorable conditions should thus always be taken into account. As a rule of thumb, loads of 1 g in the vertical direction and 0.8 g in the horizontal direction should be anticipated for worldwide transport. The shipowner will not accept any attempt by the shipper to specify a particular container slot in advance. Even notes on the bill of lading requiring loading below deck are ineffective. All shipping packages must accordingly be constructed so as to be able to withstand 0.8 times the weight of all adjacently stowed cargo and twice the mass of the cargo loaded on top. If this is not the case, appropriate protective measures must be taken. Additional rigid receptacles, frames, false decks and similar measures may be

helpful.

Modern cargo handling procedures and the ships developed for this purpose have made maritime transport faster and cheaper and, in particular, have reduced cargo handling stresses in port. In order to ensure great flexibility in terms of loading and unloading, modern ships, in particular ro/ro freighters and ferries, inevitably have poorer seakeeping ability than conventional general cargo or heavy-lift vessels.

For reasons of stability during loading, they require a high righting capacity. As "stiff" vessels they initially oppose heeling movements with a very high righting moment. The high roll moment of inertia of these vessels entails shorter rolling periods and high transverse acceleration forces. Due to the particular nature of ro/ro shipping, the ship's command is not generally able to influence the stability behavior of these ships by adjusting the weight distribution. The risk of accidents is particularly high because, given the large free surfaces in the ship, overturning cargo and the possible consequent ingress of water may result in an abrupt capsize. Most readers will remember major accidents of this kind. Inadequate cargo securing in transport receptacles such as containers, swap-bodies etc. may consequently have a very significant impact on ship safety.

Ro/ro freighter listing as a result of water ingress



Free surfaces on board always increase the risk of capsize.

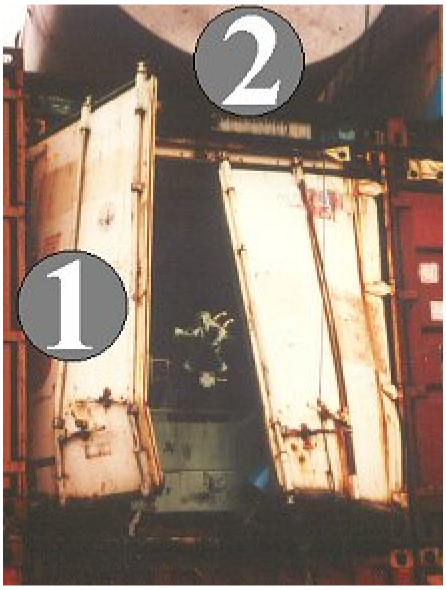
"Home-grown" acceleration forces in maritime transport are the commonest cause of cargo damage on board ship.

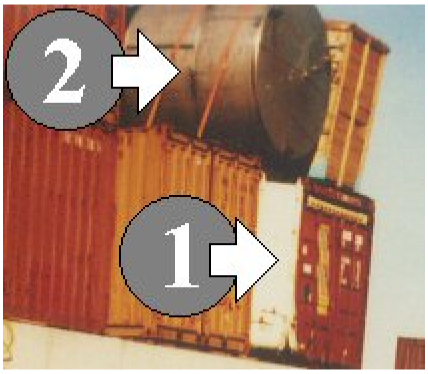
Damage caused by "home-grown" acceleration forces

Because container packers do not have the appropriate knowledge and skills, they underestimate the effect of gaps in the stow. The consequent motion has a devastating effect on the cargo.

Damage caused by "home-grown" acceleration forces

"Home-grown" acceleration can readily be identified on board ship if the stowage spaces have been subjected to similar forces, but only some of the goods have suffered damage. It is even clearer when goods stowed in an exposed location remain undamaged, while other goods suffer damage despite being exposed to lower acceleration forces. The cases on the platform at the top left were exposed to higher acceleration forces than the cargoes in the containers, which were stowed beneath or further inwards. Although the cases were only secured with a single belt each, they have only shifted slightly, while the containers and their contents have been completely destroyed.



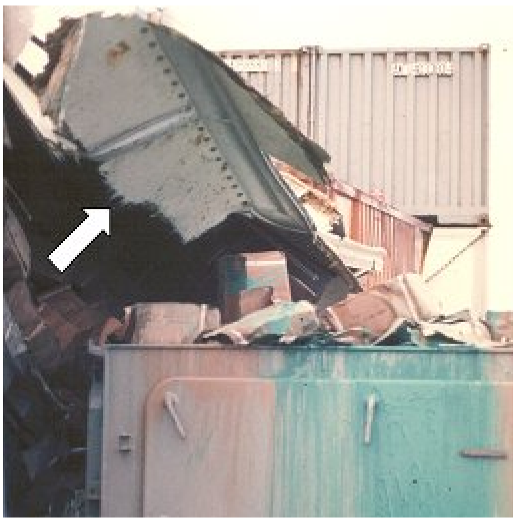


Effects of "home-grown" acceleration forces

In the lower container (1), the poorly secured machine has been set in motion and has forced the container doors open. The tank on the platform (2) stowed above is secured with only two belts and thus also inadequately. Nevertheless, it has withstood the acceleration forces and has slipped only a little. This is a clear indication that the acceleration forces were still relatively slight.

The following pictures clearly show the results of home-grown acceleration forces. It should be noted that almost all of the containers have been exposed to stresses from the inside outwards, i.e. they have bulges rather than dents.

Bulges in containers as a result of home-grown acceleration forces



Container "ripped apart" as a result of home-grown acceleration forces

The fiber structure of the plywood walls of the container in the picture above clearly reveals that the forces were acting from the inside outwards. The container was destroyed by gaps in the stow. These gaps resulted in extremely high acceleration forces and shocks.


Damage as a result of home-grown acceleration forces

Annex 13 of the CSS Code provides tools to assist in calculating **wind pressure and the effects of spray**. The details provided in this publication may possibly be of assistance in dimensioning cargo securing on open containers such as flatracks, platforms etc., but they are otherwise of interest only to the ship's command, but not to container packers working inland. As a rough guide, wind pressure may be estimated, for example for fastening tarpaulins etc., at 100 daN/m². Closed containers are spray-tight provided that they have no technical defects.

Effects of breaking-wave impact

Cargoes stowed on deck may be exposed to **breaking-wave impact**. Even for experts, the magnitude of these forces and their effects are difficult to estimate. Additional securing measures cannot prevent such effects or only to a very limited extent. While securing can never withstand breaking-wave impact, cargoes on open containers should, as a precaution, be secured against floating away.

In conventional shipping, damage prevention is the responsibility of the ship's command. Responsible ship's commands will accordingly use any means available to them to keep the effects of rough seas and breaking-wave impact as small as possible. Cargo officers will stow cargoes which are particularly sensitive or require particularly extensive securing in locations which are subjected to less acceleration. In container trade, no consideration can be given to special requirements with regard to stowage space for particular containers. Moreover, the central stowage planning offices, which prepare initial plans, and the ship's command have no knowledge as to what is loaded in the containers. Dangerous cargo containers are an exception. In this case, the contents are known and the containers receive special stowage spaces.

Container ripped open by breaking-wave impact

Summary of mechanical stresses arising during maritime transport

In very general terms, it can be stated that cargo transport units may be exposed to very different stresses during maritime transport than they are in road, rail or inland waterway transport. Unless the voyage proceeds very calmly in good weather, the containers and their cargoes will be exposed to oscillation/vibration which is primarily caused by rolling and pitching. It is almost exclusively during rolling, due to the tilt/rolling angles which arise, that shipping packages are pressed against the container walls and are squashed against the walls or the surfaces of adjacent shipping packages. The same occurs in "open" containers if parts of the cargo are pressed against the lashings or bracing. The oscillations of rolling and pitching alternately increase and reduce stack pressure. These changes peak at the moment the motion is reversed. Assuming a vertical acceleration of 1 g, a package can thus alternate between "twice its weight" and "weightless". Appropriate deductions or additions may be made for other acceleration values. When containers are incorrectly packed or the cargoes inadequately secured, the packages may shift, be dented, squashed, jumbled up etc.

Jumbled cartons in a container

2.3.4 Mechanical stresses in road transport

The short section 1.4 of the CTU packing guidelines is devoted to the stresses occurring on roads, specifically:

> *Road transport operations may generate short-term longitudinal forces upon the cargo and the CTU. They may also cause vibrations that may vary considerably due to different suspension systems, different road surface conditions and different driving habits.*

The guidelines also contain several explanatory sketches.

In a nutshell: anticipated stresses are determined by structural parameters of the goods and of the vehicle/vehicle combination, the position of the goods on the loading area, how fully laden the vehicle is, the condition of the roadway, the driver's habits etc. Special transport operations entail obtaining comprehensive information about the circumstances to be taken into account. Stowing and securing measures may then be tailored to the particular transport situation. If precise data are unobtainable, the values stated in the CTU packing guidelines, or the assumed loads specified by the relevant national organizations, should be taken into account.

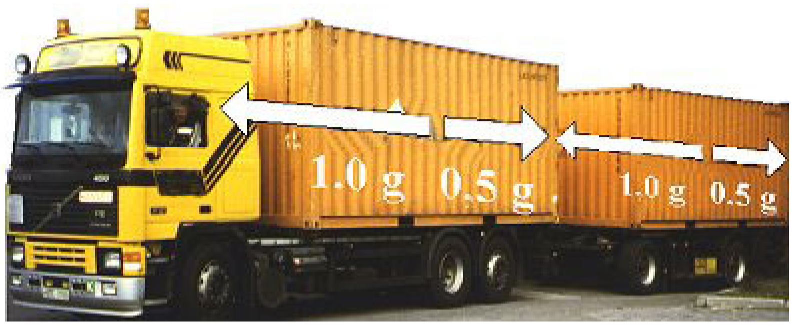
Mode of transport: road	Forward acting forces	Backward acting forces	Sideways acting forces
VDI guidelines	0.8 g	0.5 g	0.5 g
CTU packing guidelines	1.0 g	0.5 g	0.5 g
Swiss road transport regulations	1.0 g	0.5 g	0.5 g
British regulations	1.2 g	0.5 g	0.8 g

In relation to the Table (see also comment on page 89), it is stated in point 1.7 of the CTU packing guidelines that examples of accelerations are given which could arise during transport operations:

> *... However, national legislation or recommendations may require the use of other values.*

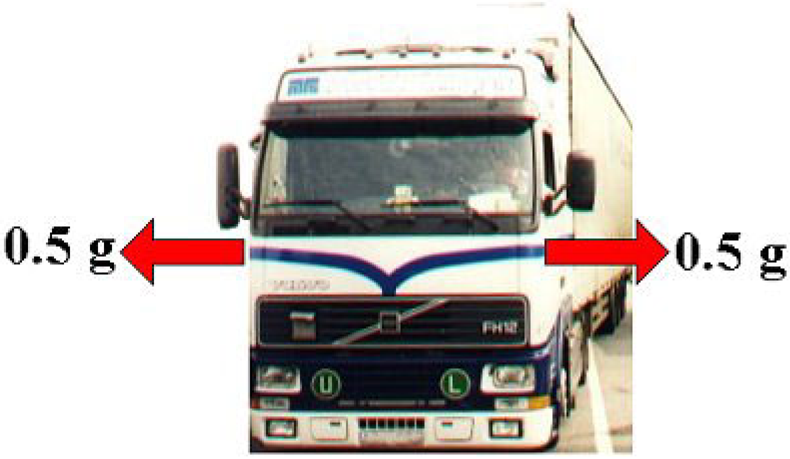
It is unsatisfactory that the tables generally state no values for vertical acceleration, although any road user will know just how much road vehicles can vibrate up and down. The Swiss road haulage association "Les Routiers Suisses" allows for upward vertical accelerations of 1 g.

Acceleration in longitudinal direction according to VDI guidelines



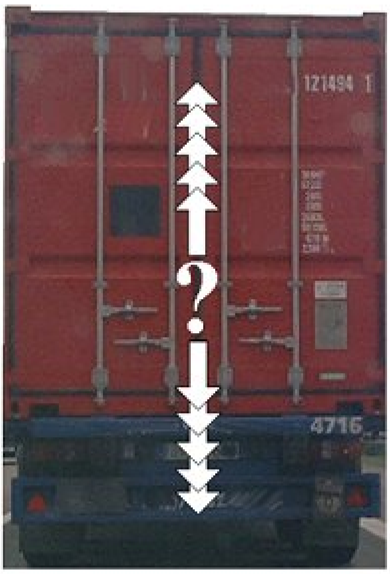
Acceleration in longitudinal direction according to CTU packing guidelines

The forward acceleration of 0.8 g according to the VDI guidelines or of 1.0 g according to the CTU packing guidelines means that forces of 80% or 100% respectively of the package weight will act on the packages in this direction. Both sets of guidelines assume backward acceleration of 0.5 g, i.e. forces of 50% of the package weight will act on the packages in this direction.



Acceleration in the sideways direction according to the CTU packing guidelines and VDI guidelines

Again, both sets of guidelines assume identical sideways acceleration values of 0.5 g. Forces amounting to 50% of the package weight will accordingly also apply sideways.

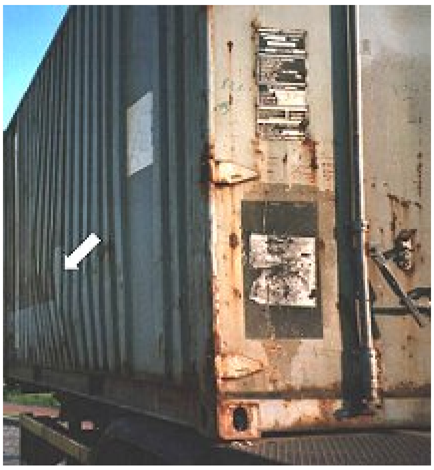


What value should be assumed for vertical acceleration?

The guidelines make no mention of vertical acceleration. Most road users will know from their own observation that loads can even lift off during road transport, i.e. values of just above 1 g vertically are quite readily achieved.

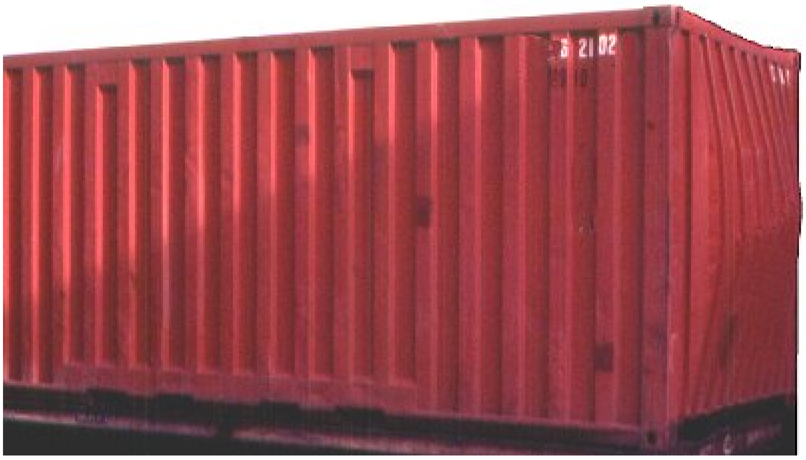
A brochure published by the former German federal railroad company, Deutsche Bundesbahn, states:

> *Considerable stresses .... in the vertical direction also occur during road delivery operations. (...) Forces of up to 0.85 times the weight-force of the load must be anticipated in the vertical direction. Measurements, filtered at 32 Hz, carried out by the Institute for automotive transport, Hanover University of Technology.*



Consequences of "home-grown" acceleration forces

As for every means of transport, the values stated in the guidelines only apply to loads which have been secured so that they cannot shift. If load items are able to move, considerably higher acceleration forces may come into play.



Consequences of "home-grown" acceleration forces in a container carried by road

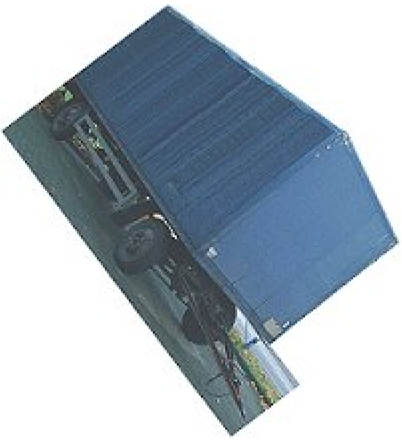
An example: 8000 kg of goods in cartons had been loaded into the container in the photograph. The articulated truck carrying the container had to brake rather harder than usual at traffic lights. Although the braking deceleration was distinctly less than 0.8 g, this maximum value will be used for the purposes of the calculation. The coefficient of sliding friction of the cartons on the container floor and between the individual cartons will be assumed to be μ = 0.3. The cartons would then have been able to exert a force of only 8000 kg x 0.5 g = 3924 daN against the front end wall of the container. As will be described in greater detail elsewhere, the loading capacity of the container end wall must amount to 0.6 times the payload. In the container shown, this would amount to 10,595 daN. The forces which actually occurred were accordingly at least 2.7 times higher. A very clear case of home-grown acceleration as a result of gaps in container packing.

Consequences of "home-grown" acceleration forces on a small truck

An example: A 1000 kg package had been loaded into the vehicle shown in the photograph. The vehicle was going around a curve with a radius of 25 m at a moderate speed of 36 km/h.
This generated a sideways acceleration of 4 m/s². A force of 392.4 daN was accordingly applied to the load. Assuming a coefficient of sliding friction of μ = 0.3, this force was counteracted by passive friction forces of 294.3 daN. The difference of 98.1 daN would never have been enough to smash through the sideboards and cause such damage to the vehicle. However, because the package was lying unsecured in the middle of the loading area, it was able to get a "run-up" and develop its destructive force.

The provisions governing the loading of road vehicles and the relevant accident prevention regulations specifically state that the load must be packed and secured in such a manner that, under normal traffic conditions, nothing can fall over, drop or roll off the vehicle and that any risk to life must be excluded. Usual traffic conditions in road transport include evasive maneuvers, hard braking and unevenness of the roadway which may occur simultaneously not merely separately. It should accordingly be assumed, as the basis for proper load securing, that a vehicle on a poor section of road suddenly has to brake hard and additionally execute an evasive maneuver. If the load can pass through such a situation unscathed, it may be deemed secure.

It should be borne in mind that the acceleration values which must be assumed for road vehicles according to VDI guidelines and the BGF, the German road vehicle maintenance employers' liability insurance association, correspond to the following tilts in degrees.



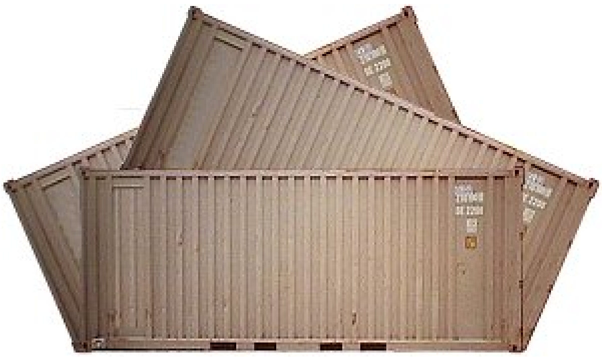
0.8 g forward acceleration in road transport corresponds to a tilt of 53°.

0.5 g backward acceleration in road transport corresponds to a tilt of 30°.

0.5 g sideways acceleration in road transport corresponds to a tilt of 30°.

The loading capacity of cargo transport units is specified in standards and the International Convention for Safe Containers. The relevant sections provide comprehensive information in this respect. However, the values will also be stated here by way of comparison with shipping stresses.

The loading capacity of the side walls of standard containers and of swap-bodies with a CSC plate corresponds to a tilt of 23.6°.



With a uniformly applied load, the front end walls of standard swap-bodies and containers must be able to withstand forces of 0.4 times the payload. This corresponds to an angle of 23.58°.

The loading capacity of the side walls of standard swap-bodies corresponds to a tilt of 17.5°.

With a uniformly applied load, the side walls of standard swap-bodies must be able to withstand forces of 0.3 times the payload. This corresponds to an angle of 17.46°.

The loading capacity of the side walls of standard containers and of swap-bodies with a CSC plate corresponds to a tilt of 36.9°.

With a uniformly applied load, the side walls of standard containers or of swap-bodies with a CSC plate which are used in maritime transport must be able to withstand forces of 0.6 times the payload. This corresponds to an angle of 36.87°.

2.3.5 Mechanical stresses in rail transport

The short section 1.5 of the CTU packing guidelines is devoted to the stresses occurring in rail transport, specifically:

> *Rail transport, in addition to subjecting cargo to vibrations (16 Hz), may also lead to shocks as a result of shunting [switching] operations. Many railways have organized their operations in such a way as to avoid shunting [switching] of railway wagons [rail cars] incurring high forces (e.g. by operating dedicated block trains) or by moving CTUs on wagons [cars] with high performance shock absorbers that are normally able to reduce shunting [switching] shock forces. It may be advisable to ensure that such operational features have been established for the rail journey.*

Several explanatory sketches are additionally included. The Definitions section of the CTU packing guidelines explains the terms shunting [switching] and block train:

> ***Shunting [switching]*** *means the operation when single railway wagons [cars] or groups of railway wagons [cars] are pushed to run against each other and be coupled together.*

Switching engine with dangerous cargo container on a special rail car

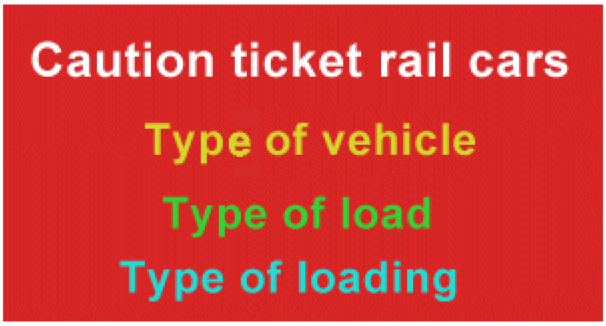
Operationally, switching includes quite wide-ranging activities which will not be addressed in greater detail here. In modern switching yards, trains are divided up and reassembled by being pushed (for example with a switching engine) up and over a hump yard, so automating hump switching operations. The speed of the rail cars as they run down the hump is kept within the desired range by special braking or driving systems. Major switching impacts are a thing of the past. In a conventional system, the rail cars running down the hump are brought to a standstill with drag shoes. If the worker laying the drag shoes makes a mistake, switching impacts involving considerable deceleration may occur. If no hump yard is available, groups of rail cars are "kicked" by switching engines and the individual cars run into the appropriate sorting sidings, where they are again conventionally brought to a standstill with drag shoes. In this case too, high deceleration values may occur when the cars collide. Lower levels of deceleration occur when the cars are pushed to activate the couplings. The UIC specifies an acceleration value of 4 g for normal switching operations. Containers are not constructed for such stresses and should not be exposed to such acceleration forces.

Rail cars with high-performance buffers, as mentioned by the CTU packing guidelines, cut the "normal" switching impacts of 4 g in half to 2 g. In Germany, these rail cars with high-performance buffers have a lower case j in their name, for example Lgjs, Sgjs, Sgjkkms etc.

Rail car with high-performance shock absorbers

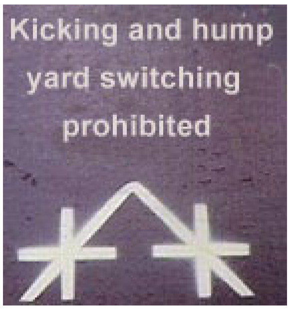
Rail cars with high-performance buffers

According to railroad operating procedures, a whole range of different rail cars must not be switched normally. This is determined by the type of rail vehicle, the type of loading or certain features.

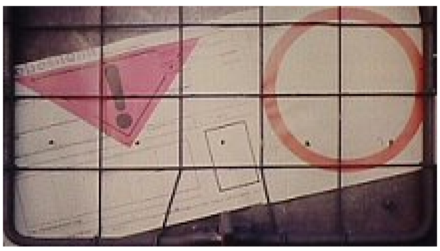


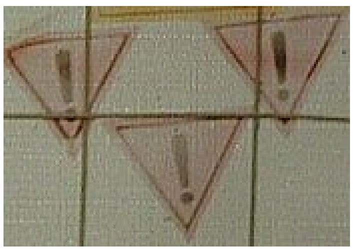
Reasons for operating under caution ticket scheme

Rail cars operated under this scheme are either specially marked "from the outset", e.g. "Hump yard switching and kicking prohibited", "Switch carefully" etc., or they may be provided with special tickets bearing a yellow triangle standing on its apex, a red circle ticket or the standard caution tickets. Rail cars operating under the caution ticket scheme are divided into three classes.



Caution ticket marking, class 1





Caution ticket marking, classes 1, 2 and 3

The CTU packing guidelines also define block trains as follows:

> ***Block train** means a number of permanently coupled railway wagons [rail cars], normally running directly between two selected terminals or entities without shunting [switching].*

Such block trains are known as "point-to-point" services or "rail cars not switched in transit". A customer of the European UIC railroads can assume that any rail cars loaded with containers or other CTUs will be transported in block trains or handled under the caution ticket scheme. Accordingly, the only values which need be taken into account from the CTU packing guidelines Table stating the acceleration forces applying in railroad transport are those for combined transport in Europe:

Mode of transport: rail	**Forward acting forces**	**Backward acting forces**	**Sideways acting forces**
Rail cars subject to shunting [switching]*	4.0 g	4.0 g	0.5 g (a)
Combined transport**	1.0 g	1.0 g	0.5 g (a)
1 g = 9.81 m/s²			
The above values should be combined with static gravity force of 1.0 g acting downwards and a dynamic variation of: (a) = ± 0.3 g.			
* The use of specifically equipped rolling stock is advisable (e.g. high-performance shock absorbers, instructions for shunting [switching] restrictions).			
**"Combined transport" means "wagons [cars] with containers, swap-bodies, semitrailers and trucks, and also block trains (UIC and RIV)".			

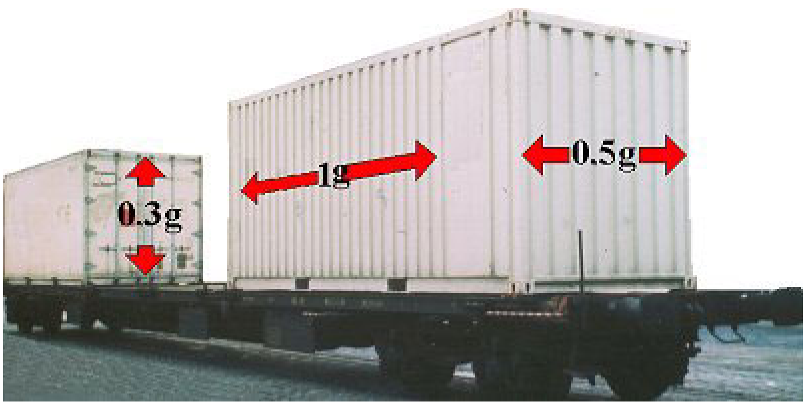
Table from the CTU packing guidelines

In relation to the Table, it is stated in point 1.7 of the CTU packing guidelines that examples of accelerations are given which could arise during transport operations:

> *... However, national legislation or recommendations may require the use of other values.*

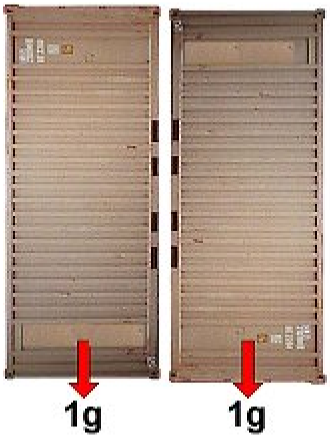
The statement in the Table: "The above values should be combined with static gravity force of 1.0 g acting downwards and a dynamic variation of: (a) = ± 0.3 g" means that the CTU packing guidelines have adopted the UIC railroad values for acceleration. In accordance with these values vertical acceleration is calculated at 0.3 g.

The same values are also specified by the VDI guidelines for intermodal transport. In road-rail intermodal transport, the following values are thus obtained: 1 g in the longitudinal direction, 0.5 g sideways and 0.3 g vertically.



Acceleration values in intermodal transport

From the standpoint of the cargo, a longitudinal acceleration of 1 g is the same as if the container had been stood up vertically, first in one direction and then the other.



Longitudinal acceleration in intermodal transport is the same as if the CTU had been placed vertically.

Sideways acceleration of 0.5 g corresponds to a tilt angle of 30°.

Sideways acceleration values in road-rail intermodal transport are identical for both modes of transport. They correspond to a tilt of 30°.

Effect of vertical acceleration of ± 0.3 g in rail transport

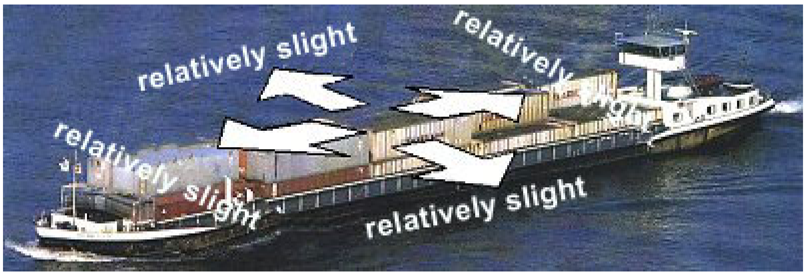
The effects of acceleration of ± 0.3 g are similar to each package in the container alternately becoming 30% heavier and then 30% lighter than its true weight.

Note: In the case of carriage by railroad companies in other continents or countries such as Africa, China, India, Canada, Russia, USA etc., information should be obtained about the prevailing conditions in each case. In some cases, stresses may be higher than in Europe. For example, in winter many containers destined for receivers close to the Great Lakes are unloaded in Halifax and carried by rail, for example to Detroit, because the sea route via the St. Lawrence Seaway is impassable due to ice.

2.3.6 Mechanical stresses in inland waterway transport

With regard to the acceleration forces encountered, an inland waterway vessel is regarded by the CTU packing guidelines as a very low risk means of transport, an opinion which is borne out in practice. Point 1.6 states:

> *Inland river and water transport is generally smooth. It will not normally exert any forces higher than those of road transport on the cargo and the CTU. Diesel engines of inland river and waterway vessels may create some low-frequency vibrations which under normal conditions should not give reason for any concern.*



Negligible acceleration forces in inland waterway transport

Higher frequency vibrations which could result in cargo damage are not a cargo securing but instead a packaging issue. Harmful vibration must be avoided in this case by means of appropriate cushioning materials. One error which is frequently encountered is providing excessive cushioning travel.

2.3.7 Mechanical stresses during cargo handling

View of a container terminal - Bremerhaven in this case

The definition stated in the CTU packing guidelines for handling reads:

> ***Handling*** *includes the operation of loading or unloading/discharging of a ship, railway wagon [rail car], vehicle or other means of transport (CTUs).*

The meaning of "ship" is common knowledge; the CTU packing guidelines definition reads:

> ***Ship*** *means a seagoing or non-seagoing watercraft, including those used on inland waters.*

The stresses occurring during cargo handling can be divided into two classes:

- stresses which act on an empty or packed cargo transport unit due to the use of suitable equipment when handling the whole CTU and those
- stresses which arise during packing and unpacking of the containers by manual methods and/or by using mechanical aids and equipment.

Handling a container with a reachstacker and top spreader

Transferring barrels into a container with a forklift truck and barrel lifter

The CTU packing guidelines define a forklift truck as follows:

> ***Forklift truck*** *means a truck equipped with devices such as arms, forks, clamps, hooks, etc. to handle any kind of cargo, including cargo that is unitized, overpacked or packed in CTUs.*

In addition to these general distinctions drawn between handling the cargo during loading and unloading a CTU and handling of the CTU itself, it is also possible to draw a distinction between

- avoidable stresses and
- unavoidable stresses


Avoidable cargo handling stresses during unpacking of a container

Packing and unpacking containers or other cargo transport units involves procedures which are no different from those previously used in conventional loading - the same risks are encountered and must be taken into account. Purely manual handling of packages generally entails exposure to more impact and dropping than in the case of mechanized handling using tried and tested industrial aids. Properly packaged and palletized goods are at little risk when forklift trucks and similar ground conveyors are used. The risk is distinctly greater for incorrectly packaged and palletized goods. However, if personnel are untrained, the risks associated with the use of mechanical aids are particularly high.


Avoidable handling stress
during container handling with a forklift truck

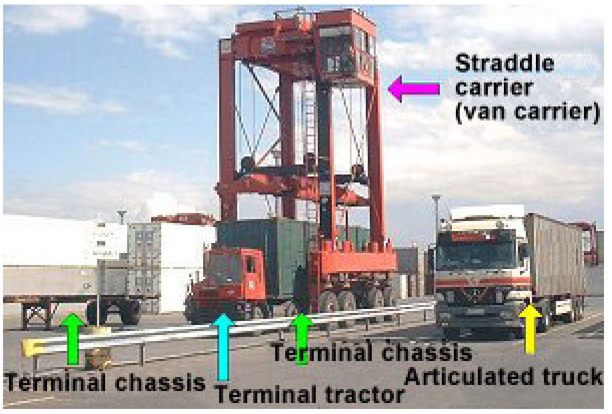
In this case, the attempt had been made to use a forklift truck to position a flatrack. In attempting to get the tines of a forklift truck under the flatrack and shift it, the fork slipped off, bending the side rail and puncturing the flatrack.


Avoidable handling stresses

If containers are handled with the equipment specially developed for this purpose, the impact stresses to which the various cargo transport units are exposed are comparatively uniform, irrespective of whether they are being transferred between road or rail vehicles or watercraft.

The CTU packing guidelines also provide some indications about cargo handling:

> 1.8 *Container movements by terminal tractors may be subject to differing forces as terminal trailers are not equipped with suspension. Additionally, ramps can be very steep, causing badly stowed cargo inside CTUs to be thrown forward or backward.*



Cargo handling activities at a seaport terminal

Terminal tractors (Tugmaster units) and terminal chassis are normally only used for moving containers on the flat. Various methods are used in terminals for this purpose. With regard to ramps, the guidelines relate to ro/ro tractors in conjunction with roll trailers. Both types of tractor require a hydraulically liftable fifth wheel coupling to allow access to the ramps. The normal chassis or semitrailers pulled by the tractors have suspension.

The stated effects on badly packed cargo have already been mentioned several times.

Ship/shore transfer with container gantry cranes and fully automatic spreaders

Intermodal cargo transfer with grapplers on a reachstacker and a gantry crane

The CTU packing guidelines also provide some information about the use of lifting gear and ground conveyors:

1.9 *Considerable forces may also be exerted on CTUs and their cargoes during terminal transfer. Especially in seaports, containers are transferred by shore-side gantry cranes that lift and lower containers, applying considerable acceleration forces and creating pressure on the packages in containers. Lift trucks and straddle carriers may take containers, lift them, tip them and move them across the terrain of the terminal.*

1.10

Deformed container floor due to the interplay of acceleration and incorrect packing methods

Even when equipment is expertly operated, stresses of approx. 1 g must generally be anticipated during cargo handling. Skilled operation assumes that the goods are lifted up and set down gently. Jerky lifting and setting down may generate very much higher g values.

Normal setting down impacts cannot always be avoided and additional crush pressures must thus always be expected. This applies both to setting down the receptacle and to setting down the spreader on the containers. If spreaders without flippers are used carelessly (the flippers center the spreader on the container), damage to container roofs must be expected. There is still a risk of damage even when manual spreaders or "overheight frames" are used.

Handling with manual spreader

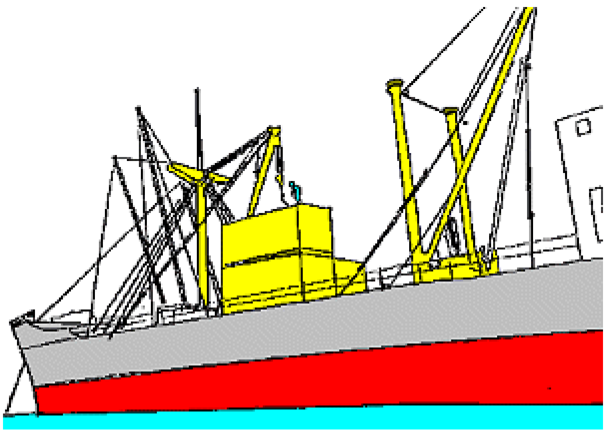
Right and left:

Overheight frame with manual locking
(in this case only set down on the container)

Especially in the case of onward carriage in countries with poor infrastructure, higher levels of stress must be anticipated during handling and unloading operations. So that no damage is caused during unpacking of the cargo transport units, packing must always be designed in such a way that the containers can be stripped as simply as possible.

Handling with on-shore container gantry cranes

It is also to be expected that containers will not always be handled as properly as they are here, but that during onward carriage they may possibly be unloaded under the most basic conditions from an old ship in the roads. "Bumping" against obstructions is not at all unusual under such circumstances. Packing and securing should be designed to withstand such occurrences.

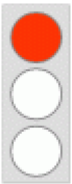


Individual containers on an old design general cargo ship
- in the roads

Handling stresses during packing and unpacking of containers are generally the result of carelessness. It is not unusual for:

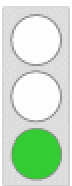
- personnel to walk on cargo which cannot withstand such loads;
- packages to be dropped during manual working;
- poorly packed pallets to come apart during forklift truck operations and for individual packages to fall out;
- packages to be punctured with the forks;
- packages to be crushed or squashed with the forklift truck;
- damage to be caused by the use of tools and cargo securing materials etc.

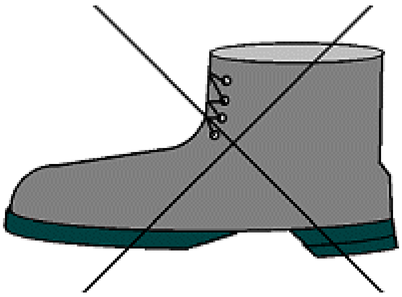
The best protection from these and the above-stated risks is good training and constant staff motivation.



The carton has already been crushed to 2/3 of its original dimensions.

Another case of human failure due to inadequate skills and insufficient supervision.



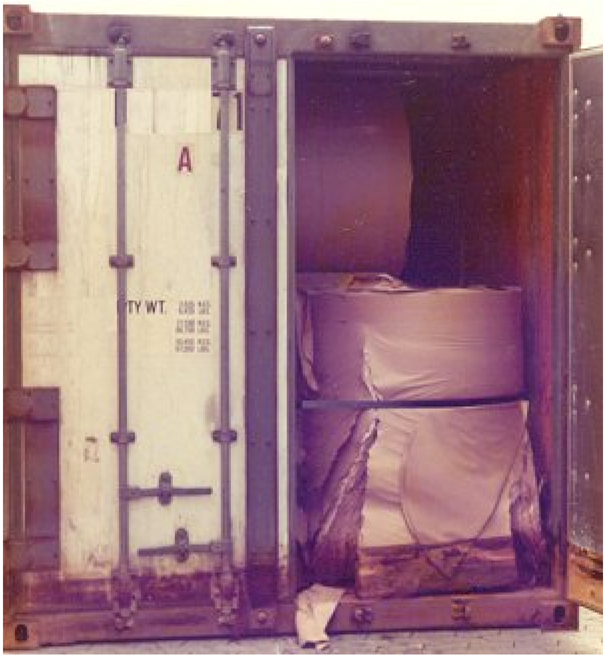


Stowing symbol:
Do not walk here!

2.3.8 Climatic stresses

Detailed information on this subject can be found in the Container Handbook section entitled "The product in the container" by Dr. Renate Scharnow, but the purpose of this section is merely to take a brief look at the subject.

An undamaged, tightly closed box container protects its contents from external influences such as ice, snow, rain, salt spray, dust, thermal radiation, ultraviolet light and other conceivable environmental influences.



Water damage in a container

However, box containers cannot provide protection from direct exposure to water because they are only spray-tight, not water-tight.

The CTU packing guidelines state that moisture damage must be avoided, point 3.2.7 reading:

> *In order to avoid cargo damage from moisture, wet cargoes, moisture-inherent cargoes or cargoes liable to leak should not be packed with cargoes susceptible to damage by moisture. Wet dunnage, pallets or packaging should not be used. In certain cases, damage to equipment and cargo can be prevented by the use of protective material such as plastic films.*

The section on dunnage indicates how the risks in the first sentence can be combated. The second sentence is very important - this principle is often ignored. Cargoes, wooden dunnage and other aids are often literally left outside in the rain before being placed in the container:

Rain-wettened cartons on wet pallets - moreover inadequately palletized

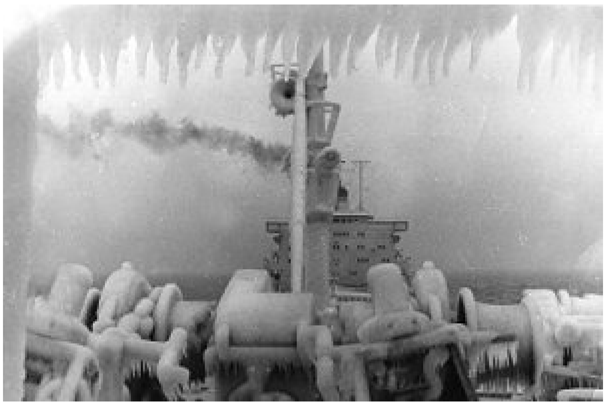
If containers are packed in the open, there is always a risk in rainy weather that ground conveyors and personnel will bring moisture into the container with them.

Cargoes in a container in which air exchange is prevented may suffer spoilage or be damaged if temperatures and

humidities during carriage reach a level which is incompatible with the goods or their packaging containers.

Point 1.3 of the CTU packing guidelines points out the negative effects of changes in temperature and humidity on container cargoes:

During longer voyages, climatic conditions (temperature, humidity etc.) are likely to vary considerably. These may affect the internal conditions in a CTU which may give rise to condensation (sweating) on cargo or internal surfaces.[1] Where cargo is liable to damage from condensation, expert advice should be sought.[1] (see Annex 1)



Ice formation on a ship

If relatively warm air is cooled to below its dew point, the resultant condensation may result in cargo damage.

Wetting damage on bags of raw cocoa due to condensation

Additional information is provided in the stated Annex 1 "Condensation".

1. Cargoes in transit may be affected by the conditions to which they are subjected. These conditions may include changes in temperature and humidity and particularly cyclic changes that may be encountered). An understanding of condensation phenomena is desirable because condensation may lead to such damage as rust, discoloration, dislodging of labels, collapse of fiberboard packages or mold formation.
2. Solar radiation can produce air temperatures under the inner surfaces of a CTU which are significantly higher than external air temperatures. The combination of these effects can result in a range of day and night cyclic temperature variations in the air adjacent to the inner surfaces of a CTU which is greater than the corresponding range of temperatures just outside.
3. Cargoes closest to the wall or roof will be more affected by external temperature variations than those in the center of a CTU. If the possible extent of temperature variations or their full significance is not known, advice should be obtained from specialists.
4. Under the circumstances described, condensation may occur either on the surface of the cargo (cargo sweat) or on the inside surfaces of a CTU (container sweat) either during transport or when the unit is opened for discharge.
5. The main factors leading to condensation inside a CTU are:

5.1 sources of moisture inside the unit which, depending upon ambient temperature conditions, will affect the moisture content of the atmosphere of the unit;

5.2 a difference between the temperature of the atmosphere within the unit and the surface temperature of either the cargo or the inner surfaces of the unit itself; and

5.3 changes in the temperature of the outer surface of the unit which affect the two factors above.

6. Warming the air in a CTU causes it to absorb moisture from packagings or any other source. Cooling the air below its dew point causes condensation.*
7. If, after high humidity has been established inside a CTU, the outside of the unit is cooled, then the temperature of the unit surface may fall below the dew point of the air inside it. Under these circumstances moisture will form on the inner surfaces of the unit. After forming under the roof, the moisture may drop onto the cargo. Cyclical repetition of cargo or container sweat phenomena can result in a greater degree of damage.
8. Condensation can also occur immediately after a CTU is opened if the air inside the unit is humid and the outside air is relatively cool. Such conditions can produce a fog and even precipitation but, because this phenomenon usually occurs only once, it seldom results in serious damage.
*9. The risk of damage and dangerous situations** can be minimized if the moisture content of the*

packaging and securing materials is kept low.

**The dew point is the temperature at which air saturated with moisture at the prevailing atmospheric pressure will start to shed moisture by condensation.*

*** For example, when goods of class 4.3 (substances which evolve flammable gases on contact with water) are packed into a container.*

Where necessary, the information provided in Annex 1 "Condensation" may have to be supplemented by additional information from other sources.

2.3.9 Biotic stresses

Detailed information on this subject can be found in the Container Handbook section entitled "The product in the container" by Dr. Renate Scharnow, but the purpose of this section is merely to take a brief look at the subject.

Both biotic and chemical stresses are closely interrelated both with each other and with climatic stresses. It may accordingly be assumed to be generally known that biotic and chemical reactions proceed particularly well when exposed to certain temperature and moisture conditions.

Biotic stresses are deemed to be present if goods, packaging or parts thereof are damaged by living organisms of whatever kind. Chewing damage may, however, cause considerable losses as may, of course, damage caused by animal excreta.

The risk is relatively low in closed containers, provided that no animals have taken up residence before packing or "sneak in" during packing. Since many rodents are nocturnal creatures, CTUs which are being packed should be closed during work breaks or at the end of a shift especially during the hours of darkness. Prior inspection of cargo transport units for tightness is a basic requirement. Insects, for example, can nonetheless still get into such closed containers which, although classed as unventilated, still have openings of small cross-section.

It will be virtually impossible to avoid damage if goods and/or packaging are infested before packing and such infestation is not noticed. In the case of "open" cargo transport units, infestation can only be prevented by providing sufficiently tight packaging or suitable preservation.

Beetle chewing damage on a paper roll

Other frequently observed phenomena include infestation of the packed goods or packaging by fungi, especially molds, bacteria or other microorganisms. Heat and high relative humidity encourage the development of mold and the multiplication of e.g. bacteria. Slight air movement also encourages growth.

It is advisable to stack cargo securing lumber with spacing battens and store it under cover; in this way, air can pass between the layers of lumber and mold formation is prevented.

While the CTU packing guidelines do not mention biotic stresses, they do point out that certain countries, wishing to prevent the introduction of pests, place specific conditions on the lumber to be used for packaging and securing.

Point 3.3.2 of the CTU packing guidelines states:

> *If a CTU is destined for a country with wood treatment quarantine regulations, care should be taken that all wood in the unit, packaging and cargo complies with the regulations. It is a useful practice to place a copy of the wood treatment certificate in a conspicuous place inside and, where appropriate, outside the unit in a weatherproof pouch.*

This primarily relates to the mandatory and usual treatment against the Sirex wasp for voyages to Australia and New Zealand (and more recently also for China). Even if no lumber is packed into the container as cargo or packaging, lumber may nevertheless still be required for cargo securing or as dunnage. In such cases, it is worthwhile having the necessary lumber appropriately treated in advance. Treated lumber should be colored in order to differentiate it from untreated lumber:

Lumber treated against the Sirex wasp - colored for differentiation

2.3.10 Chemical stresses

Substances which react together and can cause damage to the cargo or its packaging are of relevance to cargo securing.

One of the most familiar chemical reactions is corrosion and goods must be provided with protection from it by a protective coating, sealed packaging or using the VCI method. However, this is not in principle the responsibility of packing or cargo securing personnel, but instead of the shipper or his packer. However, corrosion protection must not be impaired or eliminated as a result of packing or cargo securing operations. Appropriate steps should also be taken to prevent the introduction of corrosion-promoting substances into a cargo transport unit. It must not be forgotten that the salt aerosols present in sea air can have an effect on cargoes in closed containers. Unless special precautions are taken, the risk is very much greater in all open containers.

In general, this also applies to all other solid, liquid or gaseous substances which can impair the cargo in any way. To take one extreme example: even a few molecules of a chemical, e.g. a poison, could "migrate" through one physically completely tight package into another and harm the goods inside. Preventing chemical effects requires a considerable knowledge of chemistry and so is not a responsibility which can be left to loading personnel. Appropriate instructions are absolutely essential.

Simple but nevertheless very effective preventive measures against chemical stresses are:

- Only use cargo transport units which are fit for packing, i.e. which are clean and neutral in odor
- Do not ignore basic stowage rules, for example never stow odor-releasing goods with goods which can absorb odors, unless odor contamination can be prevented by special measures
- Protect any chemically sensitive cargo from extraneous substances which could cause damage.

The CTU guidelines provide advice on fitness for loading. Point 2.2.4 requires:

> *A CTU should be clean, dry and free of residue and persistent odors from previous cargo.*

Point 3.1.4 additionally states:

> *Packing should be planned before it is started. (...) The possibility of cross-contamination by odor or dust, as well as physical or chemical compatibility, should be considered.*

It is generally the case for hazardous materials that compliance with the relevant hazardous materials regulations will prevent impairment of other goods.

3 Containers - Explanation of terminology

This section deals with the technical aspects of CTUs and the cargo securing aspect of containers, but not the general use of containers; nor is it intended to address the economic viability of using containers.

Explanation of terminology

There is some ambiguity in English about the meaning of the word "container" (from the Latin: continere = to enclose), but for the purposes of this Handbook the word should be taken to mean a shipping container, whether large or small.

The American Heritage Dictionary of the English Language defines a container as a "large reusable receptacle that can accommodate smaller cartons or cases in a single shipment, designed for efficient handling of cargo". In common American parlance, this type of container is often called a "van", although a van is defined in most dictionaries as a motor vehicle or truck or wagon.

In the past, the term container, when used in the field of goods traffic, was taken to mean standardized transport units of different types, whose dimensions were so matched to one another that they could be combined together as "transport modules". This is still generally true today; however, usage of the term has moved more and more towards large or bulky containers, which are transported by road, rail, water and (in modified form) even by air.

This part of the Container Handbook deals in particular with the packing and securing of cargoes in freight containers. However, the packing and securing instructions are equally applicable to CTUs as defined in the CTU guidelines.

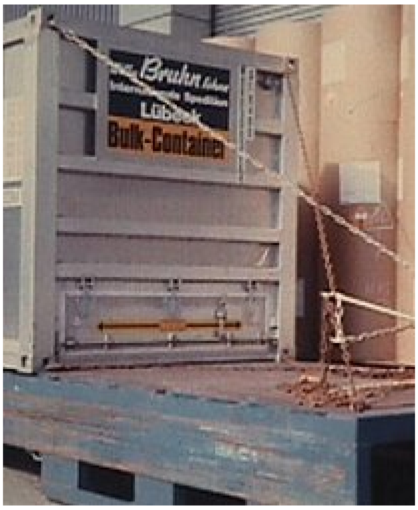
The "*Guidelines for the packing of cargo, other than bulk cargo, into or onto cargo transport units (CTUs) applicable to transport operations by all surface and water modes of transport*", in force since 17th February 1999, define the following terms:

> *For the purposes of these guidelines, the term "Cargo Transport Unit" ("CTU") has the same meaning as the expression "Intermodal Transport Unit" ("ITU") and the following definitions apply:*
> ***cargo transport unit (CTU)*** *means a freight container, swap-body, vehicle, railway wagon [railroad car] or any other similar unit.*

Freight container, in this case a partially ventilated 20' plywood box container

Swap-body **Vehicle**

Railroad car, in this case a sliding wall bogie car



Other CTUs:

Roll trailers **Cassette**

Other CTU, in this case roll trailer:

Freight container/container *means an article of transport equipment that is of a permanent character and accordingly strong enough to be suitable for repeated use; it is designed to transport a number of receptacles, packages, unit loads and overpacks together from the packing point to its final destination by road, rail, inland waterway and/or sea without intermediate separate handling of each package, unit load or overpack. The term "container" is used throughout these guidelines.*

Freight container/container, in this case 40' high-cube steel corrugated container

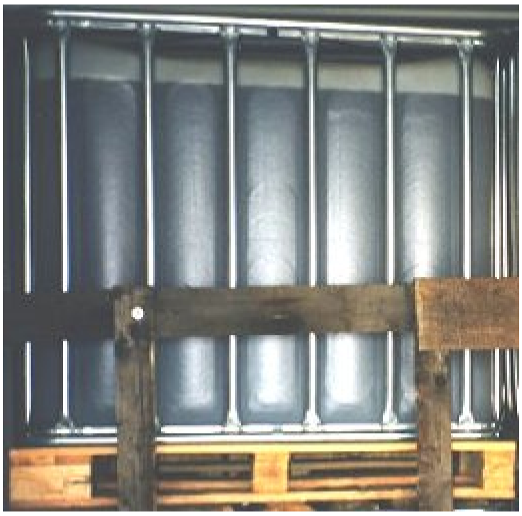
... the "permanent character, sufficient strength and suitability for repeated use" are no use, however, if a container is incorrectly packed and secured.

Damage to containers due to packing and securing deficiencies

I*ntermediate* ***B****ulk* ***C****ontainer, (IBC) means a rigid, semirigid or flexible portable packaging that:*

1. *has a capacity of not more than 3.0 m³ (3,000 liters) for solids and liquids;*
2. *is designed for mechanical handling; and*
3. *is resistant to the stresses produced in handling and transport, as determined by tests.*

Rigid IBC



Semirigid IBC

Flexible IBC, in this case a Big Bag

I*ntermodal* ***T****ransport* ***U****nit (ITU) means a container, swap-body or semitrailer suitable for intermodal transport.*

Freight container used for intermodal transport

Swap-body used for intermodal transport

Articulated truck consisting of truck tractor and trailer used for intermodal transport

__Swap-body__ means a CTU with at least four fittings for accommodating twist locks that take into account ISO standard 1161:1983 not permanently attached to an underframe and wheels or to a chassis and wheels. A swap-body need not be stackable but is usually equipped with support legs, designed especially for combined road/rail transport.

Swap-body

The term swap-bodies has come to be used in modern German parlance.

__Vehicle__ means a road vehicle or railway freight wagon [railroad freight car], permanently attached to an underframe and wheels or to a chassis and wheels, which is loaded and unloaded as a unit. This term also includes a trailer, semitrailer or similar mobile unit except those used solely for the purposes of loading and unloading.

Road vehicle


Railroad car

A distinction is drawn according to size between:

- Large containers
- Medium containers
- Small containers

This handbook deals in particular with cargo securing in large containers, with the main emphasis on those which spend at least part of their journey at sea. In principle, the cargo securing rules set out also apply to other containers. So-called pa containers are medium containers designed especially for rail transport. Small containers are used in groupage traffic and are carried by both road and rail vehicles. Neither of the above-mentioned groups will be dealt with here, however.

Depending on container design and the applicable standard, the following distinctions may be drawn:

- ISO container (also known as an overseas container or transcontainer)
- ASA container

- ISO inland container

An international standard is necessary for the standardization of transport and handling operations, e.g. to ensure uniform practice in the picking up and setting down of containers using lifting gear and ground conveyors or the marking of containers. In addition, a series of other national and international publications, some of which have legal force, cover the widest possible range of characteristics of these special containers for rationalized goods transport or give instructions for their use.

We shall not list the individual standards here, as they are of only limited relevance to packing and cargo securing. Should a particular standard be of relevance, the reader will be referred to it.
Technical Committee 104 (TC 104) of the International Organization for Standardization (ISO) was involved in drawing up many of the ISO standards. German interests were represented with regard to some standards by the ISO Container sub-committee (SC). The international standards are applied in Germany as DIN ISO or these days for the most part as DIN EN ISO.

One important regulation which has legal force has been published in the German federal law gazette as the "Internationales Übereinkommen über sichere Container (CSC)" [International Convention for Safe Containers]. The Convention defines the term container as follows:

Article II
Definitions

For the purpose of the present Convention, unless expressly provided otherwise,

1. *"Container" means an article of transport equipment*
   a) *of a permanent character and accordingly strong enough to be suitable for repeated use;*
   b) *specially designed to facilitate the transport of goods, by one or more modes of transport, without intermediate reloading;*
   c) *designed to be secured and/or readily handled, having corner castings for these purposes;*
   d) *of a size such that the area enclosed by the four outer bottom corners is either:*
      I) *at least 14 sq. m. (150 sq. ft.) or*
      ii) *at least 7 sq. m. (75 sq. ft.) if it is fitted with top corner castings.*

   The term "container" includes neither vehicles nor packaging; however, containers when carried on chassis are included.

In both DIN ISO 668, entitled "Series 1 ISO containers - Classification, dimensions and ratings" and in DIN ISO 830 "Containers - Vocabulary", containers are defined as follows:

Container: a transport container which

- *is of a permanent character and accordingly is strong enough to be suitable for repeated use,*
- *is specially designed to facilitate the transport of goods, by one or more modes of transport, without intermediate reloading,*
- *is suitable for mechanical handling,*
- *is designed to be readily packed and unpacked,*
- *has a capacity of at least 1 m^3.*

Vehicles and packaging are not containers.

In principle, the only difference between the "International Convention for Safe Containers (CSC)" and the DIN ISO standards is that the former provides for a container surface area of at least 14 m^2 or 7m^2, as a function of the corner castings, while the latter deem receptacles with volumes of 1 m^3 or more to be containers.

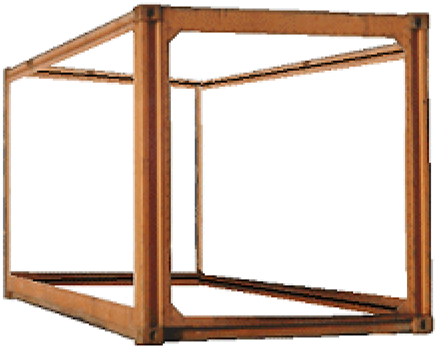
We will not at this point go into the specific definitions of the term container given in hazardous materials legislation, but if the need arises, the relevant references will be cited at the appropriate point.

3.1 Container design

A container user should be aware of the most important structural differences between containers, so that he/she is in a position to make appropriate preparations for packing and cargo securing and correctly to assess container loading capacity.

Problem-free dispatch has been assisted by the standardization of transport units, such as containers, while the standardization of certain components and some dimensions permits the use of standard handling equipment and means of transport.

We will describe fundamental components and designs first of all with reference to standard box containers. More detailed information is given under the heading "Container types".

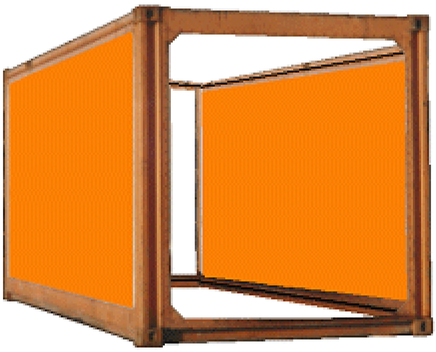


Basic container frame

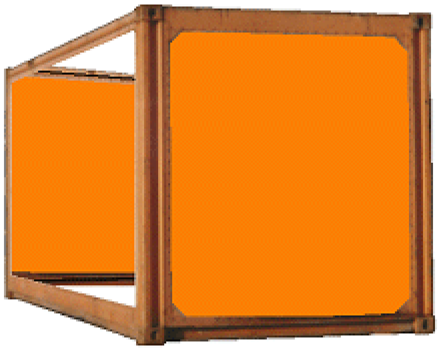
The load-carrying element of all box containers is a steel framework, consisting of four corner posts and two bottom side rails, two top side rails, two bottom cross members, a front top end rail and a door header.

Bottom cross members serve as supports for the container floor.

Additional bottom cross members are fitted between the bottom side rails, to serve as supports for the floor covering.



Side walls

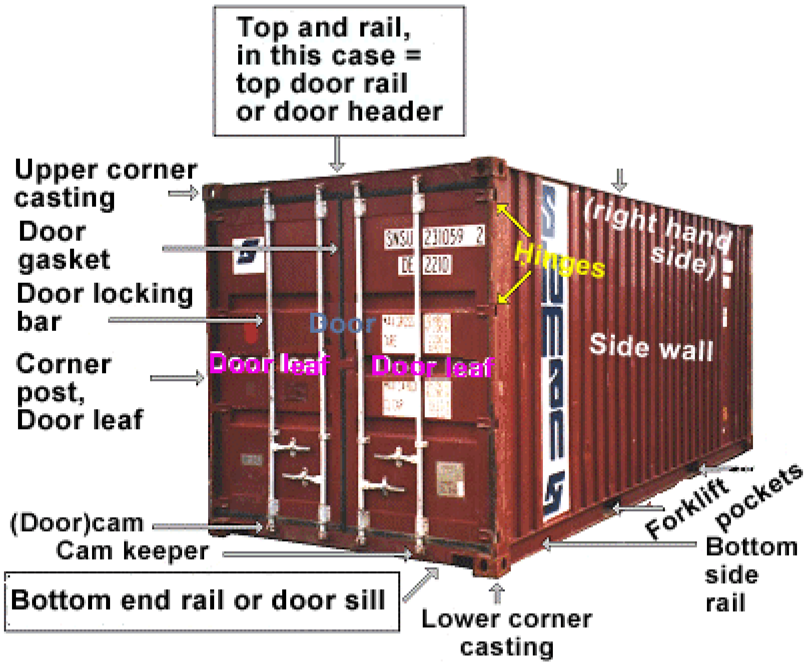


End walls

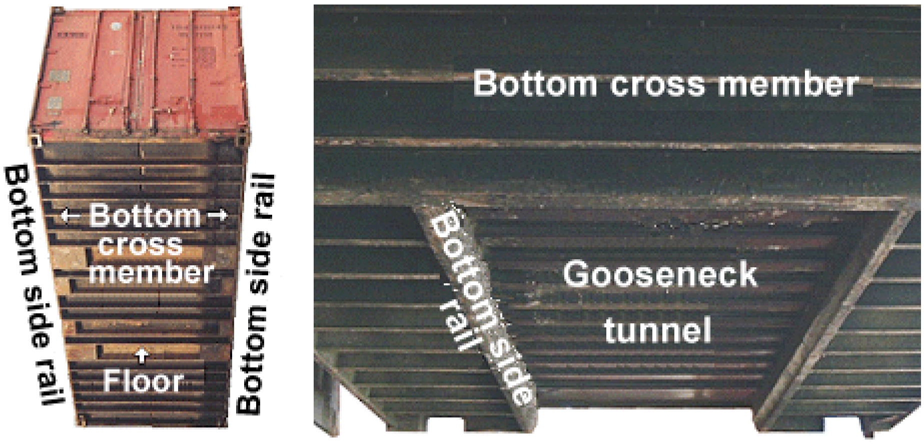
Roof panel

The side and end walls and the roof are the components of a standard box container which are capable of bearing the least load. To a certain degree, this naturally also depends on the construction materials used for them.

The following three Figures illustrate the essential components of standard box containers. Not included by name are, for example, the door bar handles, the locking components required for sealing, etc. Where necessary, descriptions of and comments about these components are provided at other points in the Handbook.



Essential components of a container



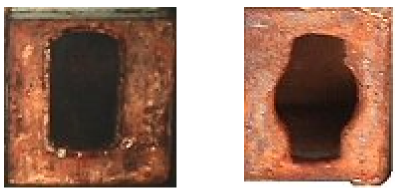
Part names in the area of the container floor

A comparison of German and English part names is given below:

German name	English name	Romanian name
Eckbeschlag	corner fitting; corner casting	
Ecksäule	corner post	
(unterer) Seitenlängsträger	bottom side rail	
(oberer) Seitenlängsträger / Dachlängsträger	top side rail	
unterer Querträger front also known as: Stirnschwelle rear also known as: Türschwelle / Türuntergurt	bottom end rail; door sill	
oberer Querträger / Dachquerträger front also known as: Stirnträger rear also known as: Türträger / Türobergurt	front top end rail door header	
Boden	floor	
Stirnwand	front end wall	
Bodenquerträger	bottom cross member	
Dach	roof panel	
Dachspriegel (e.g. in open-top containers)	roof bows	
Seitenwände	side panel; side wall	
Gabelstaplertasche	forklift pocket	
Türverschlußstange	door locking bar	
Scharnier	hinge	
Nocke	cam	
Nockenhalterung	cam keeper	
Türdichtung	door gasket	

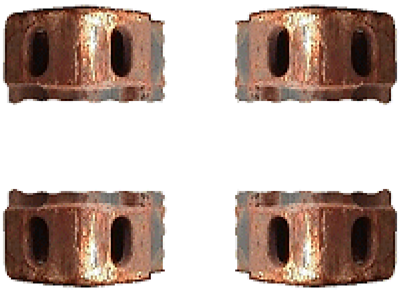
In the early days of container shipping, the majority of containers were constructed according to ASA standards, but now the containers used for maritime transport are almost without exception ISO containers.

ISO Corner Casting



ASA Corner Casting

They differ both in dimension and in the shape of the corner fittings or "corner castings". Most ASA containers, i.e. containers like those used by Sealand constructed according to "American Standards Association" standards, have since been adapted to match ISO dimensions. To simplify handling, special universal spreaders were used, which could handle both types without difficulty.



ISO corner castings - horizontal and vertical mirror images

ISO standard 1161 specifies different shapes for top and bottom and mirror images for right and left.

The eight corner castings of a container or a corresponding CTU have to be particularly strong, since they work with the corner posts and the other basic components of the container frame to absorb the forces which lock units or lashings exert on containers when they are stacked on top of one another, during handling and during transport.

Securing on board

Cargo handling

Securing on a chassis

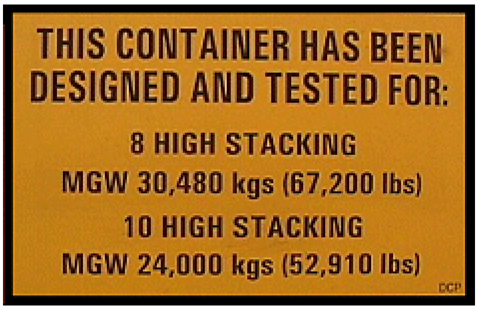
DIN/ISO standards specify certain minimum requirements for the loading capacity and **stackability** of containers; while higher levels of performance may be provided for individual properties, lower levels may not.

It must be possible to stack six ISO containers packed to the maximum weight vertically on top of one another. Maximum offset is set as follows: widthwise - 24.4 mm (1"), lengthwise - 38 mm (1½").

The actual values of modern containers are generally higher. Many are designed to be stacked eight or nine high. The maximum stacking load must be marked on the CSC plate. (More details are given in the relevant section of the Handbook).

According to safety regulations, stacked containers must where necessary be secured against toppling and shifting.

On larger container ships, the containers are stowed nine to twelve high in the hold. In such cases, the containers loaded must either be only partly full or designed to have greater stackability. The latter is generally the case with modern containers, but it is possible to use fold-out flaps in the cell guides, which subdivide the stacks.



Indicating stacking heights on a container

Inland containers are only designed to be stacked three high when fully loaded.

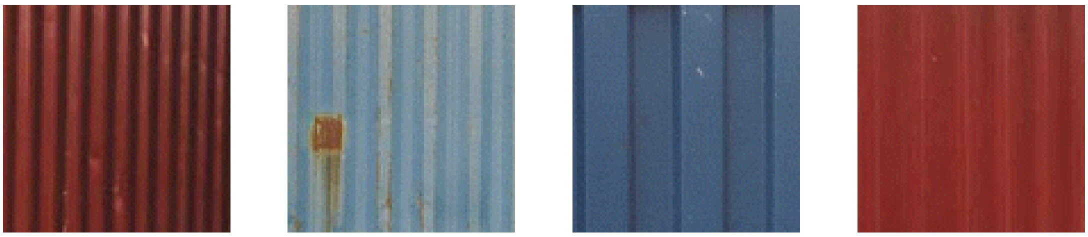
Irrespective of the material used to build a box container, it is essential for it to be **spray-tight**.

In standard box containers, the load-carrying parts are made of steel profiles, i.e. at least the entire frame including the bottom cross members and possibly also the elements serving as reinforcements, such as bottom side rails in the area of the gooseneck tunnel etc. Three main types of material are used for the walls and roof:

- steel sheet, corrugated
- aluminum sheet in conjunction with stiffening profiles
- plywood with glass fiber-reinforced plastic coating (plywood + GRP)

These are reflected in the conventional container names:

- steel container
- aluminum container
- plywood container



Variously corrugated steel sheet

In steel sheet containers, a wide range of differently profiled corrugated steel sheet may be used for the outer walls. It is protected against corrosion by painting or similar processes.

Indication of container wall material

Repair instructions on a steel container

The cost advantages of this type of container have led to its current dominance. Of all the containers currently in use, a rough estimate would suggest that 85% are made of steel sheet.

Aluminum container skin

Aluminum containers are built either with a pure aluminum skin or with a plywood inner lining; they may also either be riveted or with a smooth or lightly riveted finish.

In plywood containers, the outer walls are made of plywood coated with glass fiber-reinforced plastic (GRP). Plywood is a popular material for "coffee containers".

Container doors are often also made of plymetal, which consists of a plywood core with sheet metal adhered to it on both sides.

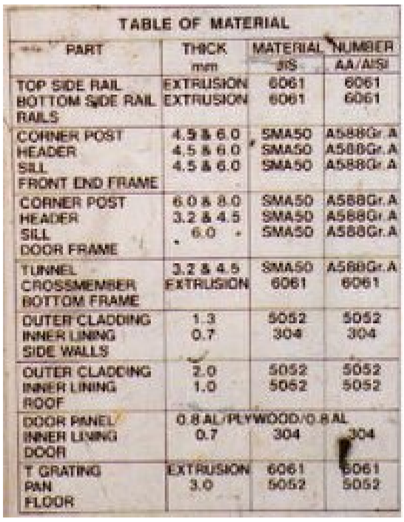
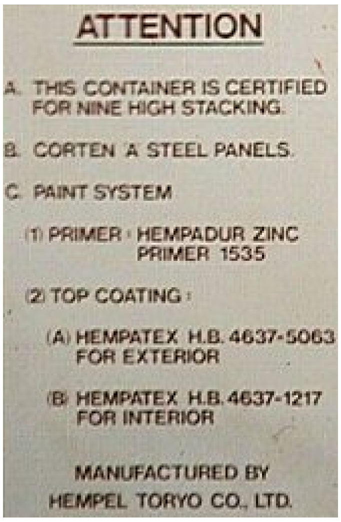


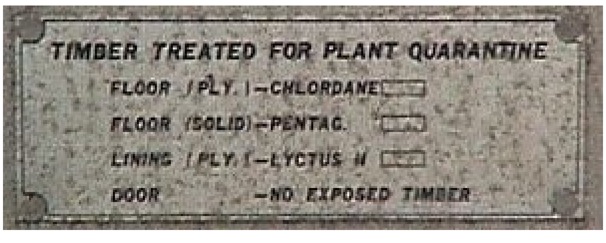
TABLE OF MATERIAL

PART	THICK mm	MATERIAL JIS	NUMBER AA/AISI
TOP SIDE RAIL BOTTOM SIDE RAIL RAILS	EXTRUSION EXTRUSION	6061 6061	6061 6061
CORNER POST HEADER SILL FRONT END FRAME	4.5 & 6.0 4.5 & 6.0 4.5 & 6.0	SMA50 SMA50 SMA50	A588Gr.A A588Gr.A A588Gr.A
CORNER POST HEADER SILL DOOR FRAME	6.0 & 8.0 3.2 & 4.5 6.0	SMA50 SMA50 SMA50	A588Gr.A A588Gr.A A588Gr.A
TUNNEL CROSSMEMBER BOTTOM FRAME	3.2 & 4.5 EXTRUSION	SMA50 6061	A588Gr.A 6061
OUTER CLADDING INNER LINING SIDE WALLS	1.3 0.7	5052 304	5052 304
OUTER CLADDING INNER LINING ROOF	2.0 1.0	5052 5052	5052 5052
DOOR PANEL INNER LINING DOOR	0.8 AL/PLYWOOD/0.8 AL 0.7	304	304
T GRATING PAN FLOOR	EXTRUSION 3.0	6061 5052	6061 5052



Materials information on containers

It is clear from these examples that containers are not generally made from a single material but various material combinations, here including steel, aluminum and plywood. The information even covers the type of preservatives used.

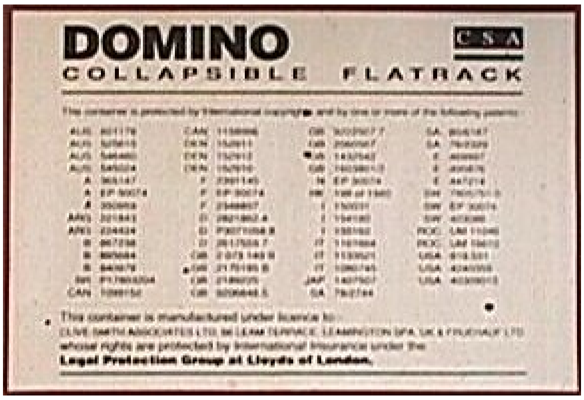


Wood treatment information

Special impregnation against insect or other pests is required for certain regions of service. Most container floors or wooden parts undergo preventive treatment.

Wood treatment information

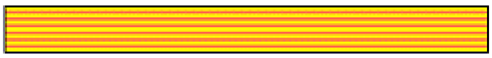
Materials used for a flatrack



Plywood floor

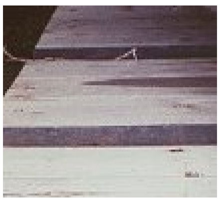
Repair to floor

Box containers are predominantly provided with coverings of plywood or textured coated board mostly 25 mm thick, more rarely 30 mm thick. Although wood is relatively expensive, it has substantial advantages over other materials: it is strong and resilient, does not dent, may be easily replaced during repairs and, when appropriately finished, has an adequate coefficient of friction. The latter does not apply to the virtually new container in the left-hand Figure, which has a mirror-bright finish.



Cross-section through a seven-ply plywood board

Planking



Steel floor

Planking is preferred for flatracks and other similar platform containers. 20' platforms or half-height open-top containers often have a floor of steel, e.g. of "tear drop" or otherwise textured sheet.

The **floors** of ISO containers have to be capable of bearing the evenly distributed payload, the emphasis being on "evenly distributed".

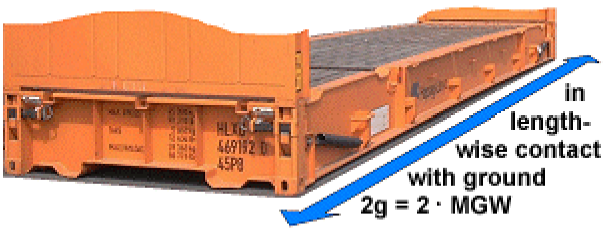
The following test criteria apply where **ground conveyors** have access to container floors.

Axle load	12,040	lbs / 5,460 kg
Wheel load	2,730	kg
Contact surface per wheel	142	cm²
Wheel width	180	mm
Wheel gage	760	mm

The wheel contact area of 142 cm² corresponds approximately to the size of a postcard. Forklift trucks with a load-carrying capacity of 2 metric tons have axle loads of just under 5 metric tons when loaded. Most 2.5 metric ton forklifts are within the admissible range. However, some electrically operated 2.5 metric ton forklift trucks reach front axle loads of over 6,000 kg when loaded. It is of course possible for even heavier forklift trucks to drive into containers, provided they are not fully loaded and the equipment and cargo dimensions allow it. It is essential to note that add-ons reduce the load-carrying capacity of forklifts, but increase the front axle load. Goods may only be stacked in box containers using equipment with a suitable telescopic mast. Using equipment with twin tires may reduce the wheel loads, but it doesn't completely resolve the issue of axle load. It shouldn't therefore be regarded as a license to use heavier equipment.

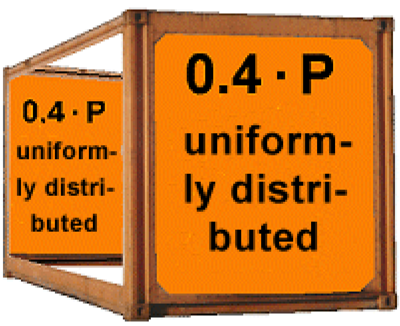
The **strength of ISO containers** is laid down in the relevant DIN standards and/or the International Convention for Safe Containers:

ISO containers must be capable of absorbing the **horizontal forces** arising during regular service at the level of the **end frames**.



Longitudinal loading capacity in the floor area

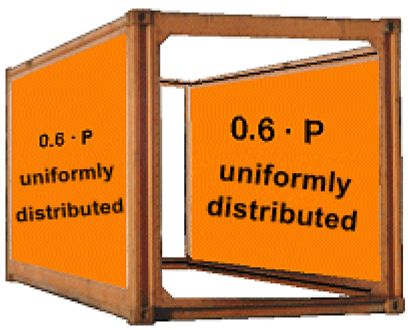
Containers must withstand loads in the lengthwise direction which correspond to external acceleration of 2 g acting horizontally on the floor fastening elements. This takes into account loads which are transmitted via twist locks and other vehicle locking elements to containers. Special railroad container cars with hydraulic shock absorption limit forces to 2 g; examples of these cars are Lgjs, Sgjs and Sgjkmmns cars and other cars with a j in their name, the j indicating high-performance (long-stroke) shock absorbers or buffers.



According to the CSC, **end walls** must be so constructed that forces of 0.4 times the uniformly applied payload may be absorbed, i.e. 40% of the container payload or 0.4 g. Higher or lower values should be marked on the containers.

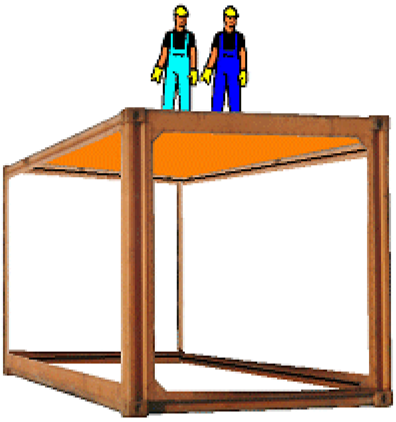
End wall loading capacity

The loading capacity of the **side walls** must correspond to 0.6 times the uniformly applied payload, i.e. 60% of the payload or 0.6 g. Higher or lower values should again be marked on the containers. More details are given in Section 3.1.2 CSC & structural and testing regulations".



Side wall loading capacity

Since the values for end and side walls are valid only for large-area loads, any point loading of the walls should be avoided. Because the weight-carrying capacity of many general purpose containers is not fully utilized, loading is kept below the maximum values in the case of compact and even packing. However, if the rate of utilization is high and/or uneven, countermeasures must be taken.



In the case of **container roof panels**, an evenly distributed 200 kg load may be applied to a surface area of 600 x 300 mm, so meaning that two people may stand next to one another on the container roof. Under no circumstances may container roof panels be covered with cargo.

Some containers are fitted with forklift pockets for handling with ground conveyors. Appropriate regulations relating to the required dimensions may be found in appendix C of ISO 1496/1. The pockets are cavities formed crosswise in the floor structure and allow insertion of the forks from the side; the forks must be pushed fully into the pockets. Forks which are too short must under no circumstances be used for lifting, since they may cause damage to the floor.

Unmarked forklift pockets on a box container.

The forklift pockets generally only allow handling of empty containers. Packed containers must not be picked up in this way unless specifically permitted. This is not the case here; hence, the container may only be picked up with forks when empty.

Forklift pockets on a flatrack marked EMPTY

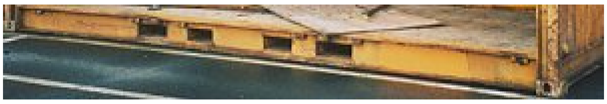
Forklift pockets on a flatrack not marked EMPTY

Both containers may only be picked up when empty.

For the most part, no marking is provided or no explicit instruction is given to pick up only empty containers, missing. To rule out errors, marking should be made a requirement.

Marking variant: the arrows bear the mark "Tare".

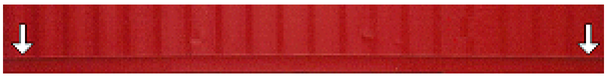
The containers shown here merely bear the marking "Tare" at the inner forklift pockets. The outer pairs of pockets lack markings or symbols. It is obvious here that the arrangement of these pockets also allows handling of the full container by forklift truck, but one can never be sure. This example shows that there is a need for marking to be mandatory.



Forklift pockets on a "tilt" container

With this container, it is even less certain how the forklift pockets are to be used. Standardized regulations and compliance therewith in practice could help in the avoidance of many losses resulting from the incorrect use of these components.

Straddle carrier recess



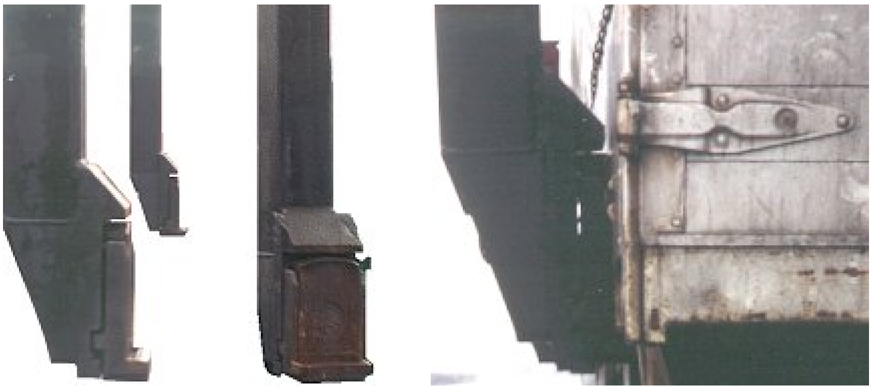
Some containers have a recess along the longitudinal sides which allows the containers to be picked up using straddle carrier load suspension devices for transport within cargo handling facilities. Straddle carriers are specially built (low) van carriers with which loads may be lifted but not stacked.

Handling a swap-body with grappler in grappler pockets

Grappler pocket in a semitrailer

Grappler pocket in a swap-body

Grappler pockets are slots or recesses in the bottom side rails of containers or other CTUs, especially inland containers and swap-bodies. Grapplers slot into them during cargo handling. Such grapplers may also be used with gantry cranes, if no spreaders are used. Grappler pockets also allow direct pick-up of the containers with the tongs of a van carrier.



Detailed images of grapplers

Gooseneck tunnel

Many containers have recesses in the bottom of the front end This centrally located recess is known as a gooseneck tunnel. A large number of CTUs, especially flatracks have them at both ends. The tunnel does not have any effect on loading space, the inside of the container floor or the flatrack loading area being flat. This recess serves in centering the container on a gooseneck chassis.

Container with gooseneck tunnel on a normal container chassis

Container with gooseneck tunnel on a gooseneck chassis

Containers with goosenecks can be carried on both normal chassis and gooseneck chassis. Containers without goosenecks can only be carried on normal chassis. Depending on the construction of the chassis, a lower road vehicle overall height may be achieved with gooseneck chassis. In this way, many articulated trucks can see their height reduced by approx. 150 mm.

40' flatrack with gooseneck tunnel

20' flatracks without gooseneck tunnel

In accordance with the standards, gooseneck tunnels are only provided for 40' containers.

3.1.1 Container design and types

3.1.1.1 Container design and types, Part 1

Over 50 percent of the containers available internationally belong to shipping companies. Alongside these are a large number of leasing companies, which lease their containers both to shipowners and to direct customers. Containers belonging to forwarders tend to carry dry and liquid bulk goods, for which bulk and tank containers are mostly used. Specific details about the appearance of the containers, their external and internal dimensions, their weights and volumes, temperature control, cargo securing equipment and other special features may in general be found in the brochures published by the respective companies. Of necessity, the following can only deal with a few types of container.

According to DIN ISO 4346 of January 1996, a distinction may be drawn between the following types:

- General purpose containers
- Bulk container
- Named cargo containers
- Thermal containers
- Open-top containers
- Platform containers
- Tank containers
- Air/surface containers Further distinctions are drawn within these groups depending on design and principal characteristics. Information relating to the respective code, the group and type code, is to be found in Section 3.4 "Size and type codes".

  Over the years, expressions have become established which do not always correspond to the standards or which are used in addition to the standard expressions. Some of these need to be explained.

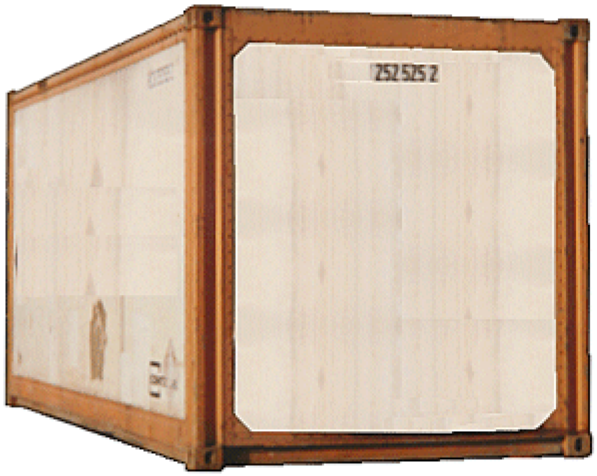
  The term **standard container** was used for the first containers in their basic form. As these were closed and were primarily suitable for the loading of general cargo, they were/are also known as **general purpose containers**, **dry cargo containers** or **box containers**. The initial height of 8' has already very nearly been consigned to history. Most box containers have an external height of 8' 6". Unventilated general purpose containers have openings on either one or both end(s).


Unventilated general purpose containers of sheet steel

The two steel containers of virtually identical construction can be designated standard containers. Both containers have an external height of 8'6" and no gooseneck tunnel. This is stated in coding 2210 on the one hand and 22G1 on the other. Both containers have forklift pockets and straddle carrier recesses.


Vents in a container

Containers equipped with such vents also count as unventilated general purpose containers, although they have small vents in the upper part of the cargo space.



20' plywood container with vents in the top side rail

This container too falls into the category of "unventilated general purpose container" although individual vents are provided all the way along the upper part of the cargo space.

Containers with end doors and side doors occupying the entire length

Another subgroup of unventilated general purpose containers specified in DIN EN ISO 4346, January 1996, has "openings at one or both end(s) plus full openings on one or both sides".

Container with end wall doors and partial openings at the side

Another subgroup consists of container with "openings at one or both end(s) plus partial openings on one or both sides".

The expression **high-cube container** originally covered all containers higher than 8' 6". The expression is now used in practice almost only ever for containers which have an external height of 9' 6". Particular attention needs to be given to possible height restrictions when these containers are carried by for road and rail. It may be necessary to use special chassis or carrying cars.

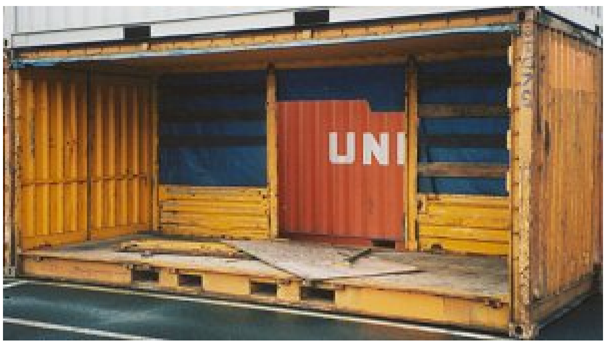
Comparison of a high-cube container (9' 6") with an 8' 6" container

The yellow and black marking on the top edges of the high-cube container serves as a warning about its height. More details about operational markings are given in Section 3.5.

40' Container: left 8'6" high, right 9'6" high (high-cube)

40'-Containers have a larger volume-to-payload ratio than 20' containers, i.e. they are suitable for goods with a higher cargo stowage factor.

Open-sided containers (OS) have solid end walls and a solid roof panel. The sides may be closed at the bottom by folding down wooden, aluminum profile or steel sheet side walls, which may be divided into sections. Roof bow holders and roof bows are provided for the upper part, which may be covered with tarpaulins. The container is packed from the side. Open-sided containers also exist which are open only on one side. If bars are positioned over one open side, the containers can be used for transporting livestock. Another variant is the "folding side wall" container, a type of inland container.



Open-sided container, here in the form of a "tilt" container with end wall door

Open-sided container, here in the form of a "tilt" container with end wall door

As is clear from the pictures, open-sided containers are also available with doors at the rear of the container.

The statement found in many brochures to the effect that "lateral load securing consists of planks, which are suspended between the removable central support and the corner posts" is not to be trusted. It is essential to check what forces these structures can absorb.

Open-top open-sided containers (OTOS) combine the features of open-sided and open-top containers, i.e. the roofs and sides are open and need to be covered with tarpaulins.

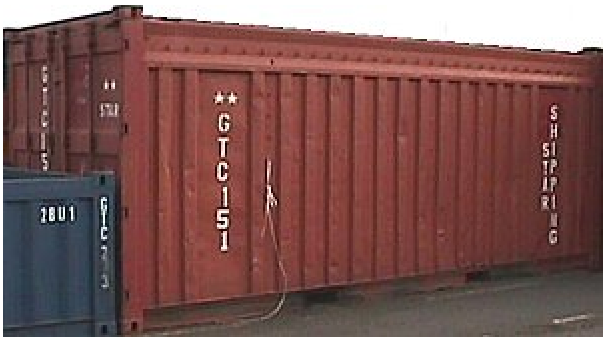
Since it is American transport that gave rise to the 8' wide standard overseas container, these containers are not suitable for the interchangeable pool pallets used in Europe, which have dimensions of 800 mm x 1,200 mm. To counter this problem, pallet-compatible containers 2.50 m in width have been constructed, which must not, however, be confused with the pre-existing inland containers 2.50 m in width.

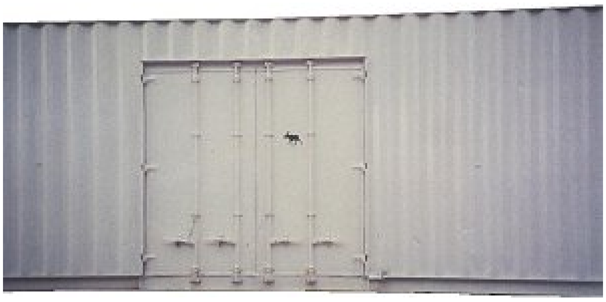
Pallet-compatible 40' containers

20' x 8' 6" container with side doors

2.50 m wide 20' inland containers provided by DB (German Railroads)

20' x 8'6" container with two end wall doors





General purpose container - special design with side doors

10' wide general purpose container

General purpose containers with special features are intended to make it possible to transport particular cargoes which could not otherwise be safely transported without damage. **Containers for hanging garments** belong to this group: they are equipped with clothes rails which are attached to special supporting bars. Textiles, hanging on coat-hangers, can be carried in these containers.

Passively ventilated containers, also known as **ventilated containers**, hardly differ from standard containers in external appearance. They are used for the most part to transport organic cargoes with high moisture contents, such as coffee and cocoa beans. Special equipment is intended to ensure that, as far as possible, sweat is prevented from forming. In general parlance, the containers are also named after the type of cargo carried in them, hence the widespread use of the expression **coffee container**. There are two basic variants:

- Containers with natural ventilation use pressure differences between the internal and external air for air exchange purposes. Warm air rises in the container and exits at the top through the roof ventilation strips. Cooler external air then enters through the floor ventilation strips.

- Forced ventilation containers use fans and air ducts and/or ventilation flaps to achieve the necessary air exchange.

Container vent slots or air openings are often constructed as a labyrinth to prevent the penetration of spray or precipitation. Often, there are openings in the bottom and top side rails, which form regular air ducts. Sometimes, only relatively small, perforated areas are provided at regular intervals in the outer skin.

DIN EN ISO 6346, January 1996, lists ventilated general purpose containers under Code V, allocating to them either group code VH or type codes such V0, V2 or V4. A distinction is drawn between:

- Containers with non-mechanical ventilation at the lower and upper parts of the cargo space
- Containers with mechanical ventilation installed in the container and
- Containers with mechanical ventilation located outside the container.

General purpose containers with non-mechanical ventilation

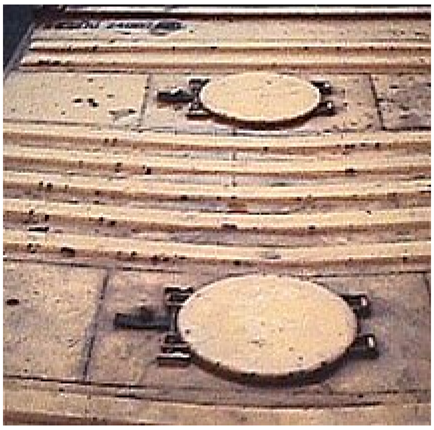
Non-mechanical ventilation at the upper and lower parts of the container

General purpose containers with mechanical ventilation installed in the container

There are plenty of other designs of general purpose container, in addition to those described above. A more unusual example is the container illustrated below.

General purpose container with flaps on the end and side walls

Dry bulk containers or **bulk containers** may be used to transport loose, free-flowing goods. DIN EN ISO 6346 of January 1996 distinguishes, under Code B, between the group codes BU and BK as well as various type codes for non-pressure-resistant dry bulk containers which are closed or air-tight and dry bulk containers with horizontal or tipping discharge pressure-resistant at test pressures respectively of 150 kPa and 265 kPa.



Above and right:
Loading hatches and discharge outlets in different bulk containers

Externally, normal bulk containers are of identical construction to standard containers except for the loading hatches and discharge outlets. The loading hatches or domes are arranged in the roof.
To gain access to these, some containers are provided with swivelable ladders. To prevent contact between the cargo and the container walls, "inlets" or liner bags may be introduced into the containers and fixed in place. The unloading hatches are normally at one of the ends, generally incorporated into the doors. Sometimes, short hoses are also incorporated, so as to be able to direct the cargo as it is unloaded. Less frequently, the discharge outlets are arranged at the side. In all the above cases, unpacking is achieved by the force of gravity, generally assisted by tipping the containers.

Chassis with tipping equipment for emptying bulk containers

Some **special dry bulk containers** resemble tank containers. In addition to emptying by gravity, some containers are available which may be emptied by means of compressed air.

Bulk container with compressed air-assisted emptying

Bulk container

By fitting "inlets" or liner bags, normal general cargo containers may also be used as bulk containers:

"Inlets" in a general purpose container, for transporting bulk cargo

Reusable "inlets" are available, as well as single-use "inlets" or disposable liners.

DIN EN ISO of January 1996 specifies under Code S and group code SN "named cargo containers". Examples of these include containers for transporting livestock (type code S0), containers for transporting automobiles (type code S1) and containers for transporting live fish (type code S2).

3.1.1.2 Container design and types, Part 2

Thermal containers are divided into refrigerated, refrigerated/heated and merely insulated types. A distinction is also drawn between those with fixed and removable equipment. Refrigerated or heated containers allow goods to be transported irrespective of ambient temperature. The question of whether the container heats or refrigerates is relative. Nonetheless, the term **refrigerated container** or reefer has become established in common parlance. The correct term would be **temperature-controlled container**.

Thermal container with integral unit - rear

Thermal container - side and end with integral unit

Depending on container quality, the entire outer skin may be appropriately insulated, thereby reducing the internal dimensions of the container. According to ISO 1496/2, the internal width must amount to 2200 mm. The container (reefer) floor is generally made of T-shaped aluminum profiles and is also known as a T-grating. The floor is strong enough to allow access by forklift trucks. The type code distinguishes between thermal containers according to type of refrigeration unit and/or coefficients of heat transmission (k values). The temperature of **insulated containers** may be controlled by external refrigeration units.

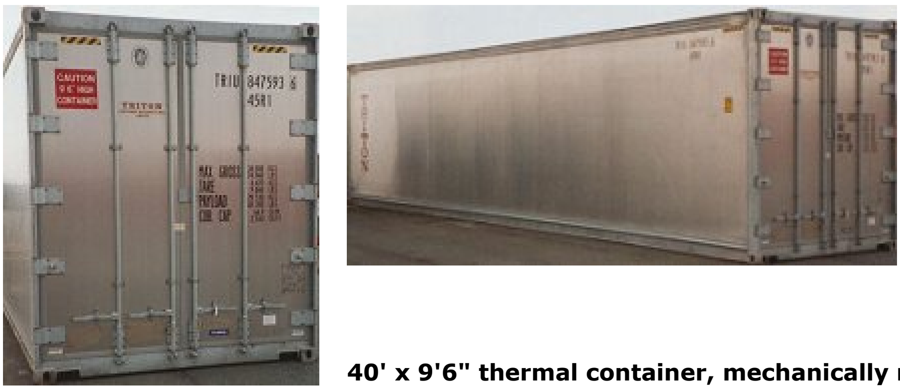
Mobile refrigeration unit, in this case in stationary use

Mobile refrigeration unit, for stationary use

DIN EN ISO 6346, January 1996 lists thermal containers under Code R, namely:

- mechanically refrigerated under group code RE and type code R0
- mechanically refrigerated and heated under group code RT and type code R1
- self powered mechanically refrigerated under group code RS and type code R2 and
- self powered mechanically refrigerated and heated under group code RS and type code R3

20' x 8'6" thermal container, mechanically refrigerated/heated



40' x 9'6" thermal container, mechanically refrigerated/heated

Code H of the same standard covers refrigerated and/or heated thermal containers with removable equipment, with group code HR applying to:

- refrigerated and/or heated with removable equipment located externally, coefficient of heat transfer K = 0.4 W/(m² x K), type code H0
- refrigerated and/or heated with removable equipment located internally, type code H1
- refrigerated and/or heated with removable equipment located externally, coefficient of heat transfer K = 0.7 W/(m² x K), type code H2

Group code HI covers insulated containers, namely:

- Type code H5 = insulated, coefficient of heat transmission K = 0.4 W/(m²·K)
- Type code H6 = insulated, coefficient of heat transmission K = 0.7 W/(m²·K)

These containers also resemble standard containers externally, but inside they have a heat-insulating lining, generally of polyurethane foam-based insulating material. Their wall thickness of 50 - 100 mm reduces stowage space a little compared to normal containers. The insulation is intended to protect the cargo from over-rapid temperature variations. If lower temperatures or refrigeration are required, refrigerants may be added. Ice is seldom used nowadays, since it requires special ice boxes; instead, dry ice is often used. Another method is to vaporize liquefied gases. Such containers are used for the most part to carry heat-sensitive cargoes.

Insulated containers and refrigerated containers may also be used without refrigeration or heating. Since temperature variations in the container are delayed relative to the external temperature, using such containers can be entirely appropriate for certain goods.

Refrigeration and/or heating may be achieved by:

- compressors directly driven by electrical motors
- compressors directly driven by internal combustion engine
- externally generated cooling or heating air

The electrical power required for driving refrigerating/heating machines is supplied by on-shore or on-board power supply systems or by a separate generator driven by an internal combustion engine, diesel engines mostly being used for this purpose. A distinction is drawn between fixed generators and so-called clip-on generators, which are only fitted on a temporary basis.

Integral refrigerating/heating machine for connection to on-shore or on-board power supply system

Fixed refrigeration units (integral units) reduce the useful length and payload of containers.

Clip-on units for temporary fitting to thermal containers

Clip-on units increase the overall length of the containers. These heating/refrigerating machines are individual units which may be stored on shore or on board and temporarily attached to the end walls of containers. Each apparatus may be individually adjusted and does not affect the cargo space atmosphere for other containers. Supply air is input at the bottom and return air is extracted at the top.

Openings for supply and return air in an external unit

Such containers are also known as "porthole containers", the name arising from the similarity between these openings and the round ships' windows known as portholes.

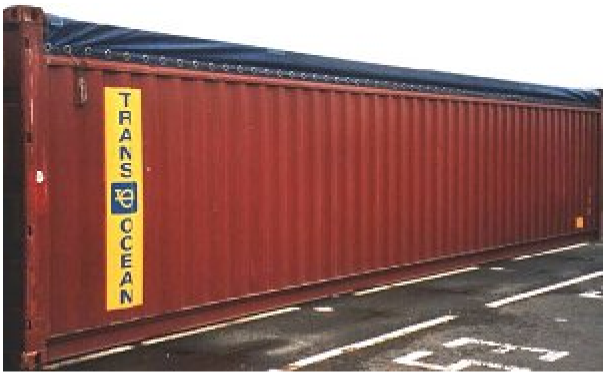
Thermal container/insulated container with externally fitted supply device

Supply device for a thermal container - detail

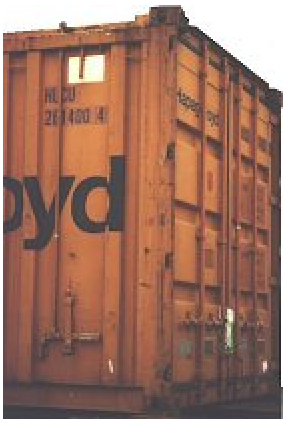
Externally generated cooling or heating air may be supplied via on-shore or on-board central refrigeration systems. Containers supplied by this system also have two openings in the end wall for the supply and removal of cargo space air subject to artificial temperature control.

The term **Conair container** is a brand name often used for "insulated container".

Open-top containers are suitable in general for all types of general cargo but especially for heavy, overheight cargo. Since their roofs are openable, they may also be packed from above. They have doors at least at the rear and their roofs are openable or removable. The roof covering consists either of a tarpaulin supported by roof bows or a solid, fully removable hard-top. Containers with the latter type of roof covering are known as hard-top open-top containers.



Open-top container with tarpaulin and roof bows



Above and right:
Hard-top open-top containers

Cover removed from a 20' hard-top open-top container

So that it is possible not only to introduce cargoes from above but also to load overheight cargoes through the doors, some containers have removable or swing-out top members or top door rails. This also facilitates packing using lifting gear at floor level.

Open-top container with top member removed

The roof bows of an open-top container serve both to support the tarpaulin and to stabilize the whole container. Such containers are therefore also made wholly of steel, so that the structure is still sufficiently stiff despite the absence of a roof. If overheight cargoes are carried, the stabilizing effect of the roof bows is absent. In some cases, therefore, it would be sensible to investigate whether it would not be equally possible to use flatracks or indeed whether that would not be the better solution from the point of view of cargo securing.

Half-height open-top containers are open at the top, as their name suggests. There are two types in existence: either completely open or with a tarpaulin and roof bows. The rear door may often be folded down and used as a ramp.

20' and 40' half-height open-top containers, with and without cover

DIN EN ISO 6346, January 1996 lists open-top containers, abbreviated as OT, under Code U. The group code for all such containers is UT. The following types are distinguished by the type codes indicated:

- U0 - Opening(s) at one or both end(s)
- U1 - Opening(s) at one or both end(s) plus removable roof in end frame
- U2 - Opening(s) at one or both end(s) plus opening(s) on one or both sides
- U3 - Opening(s) at one or both end(s) plus opening(s) on one or both sides plus removable top members
- U4 - Opening(s) at one or both end(s) plus opening(s) on one side plus full openings on the other side
- U5 - Full, solid side and end walls (no doors)

20' x 8' x 4'3" Half-height open-top - external and internal view

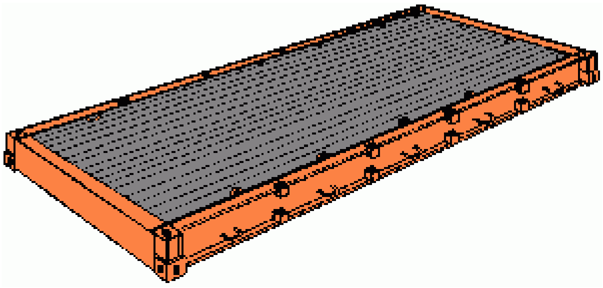
With this container, the rear end wall (at the front in the left-hand picture) can be folded out and used as an access ramp for forklift trucks. A warning is attached:

Warning about the "ramp" of a half-height open-top container

The old, but still valid, number combination 4351 would today be replaced by the code 42U3.

Two OTs: each with rear doors and removable top members

Platforms and flatracks are also known in common parlance as **open containers**. Although such containers may have special equipment, such stanchions, fold-down end walls, lashing equipment etc., they are often described in specialist literature as **containers without additional equipment**.



Platform: 20' long, 8' wide and 1'1¼" high

Platforms consist of reinforced container floors with sheet steel or planking. A large number of lashing points are provided for cargo securing; these may be welded-on or recessed lashing lugs or rings, or lashing bars attached to the outsides of the side rails.

Two 20' platforms 1'1¼" high

If agreed with the shipping companies, several platforms may be combined to form larger loading areas for carrying oversize goods. Acceptance and delivery then require special attention and coordination of operations between the ship's command, shipping companies and terminal operator is recommended. When empty, platforms can be stacked into piles to save space during transport. Since loaded platforms are not stackable, they are loaded on board ship as the top layer of a hold or deck stack. If a ship's cell guides are equipped with flaps, any stowage space can be used. 20' platforms are generally 335 mm (1'1¼") high, while 40' platforms are generally 610 mm (2') high). There are 40' platforms with gooseneck tunnels at both ends.

Flatracks, also known as flats, consist of container floor and end walls. Flatracks with folding or collapsible end walls or end frames are commonly known as collapsible flats or collapsible flatracks.

20' flatrack with fixed end walls

Flatracks are also known as "open-top open-sided containers".

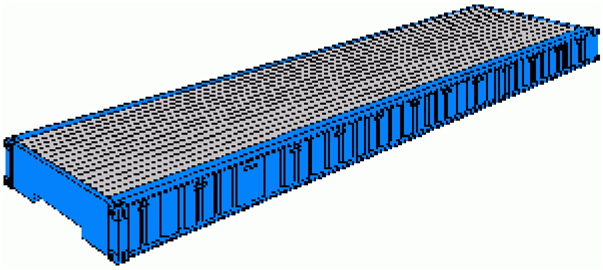
2.50 m wide 20' flatrack, one of the inland containers provided by DB (German Railroads)

20' collapsible flatracks, erected and collapsed

The advantage of collapsible flatracks is that several unloaded flats can be stacked on top of one another to save space during transport. For cargo securing purposes, the flats are equipped with lashing bars, lugs or hooks of appropriate strength. Stanchion pockets and insertable stanchions are often provided. If agreed with the carriers, a number of flatracks may be combined together so as to be able to transport particularly large items of cargo.

3.1.1.3 Container design and types, Part 3

DIN EN ISO 6346, January 1996 allocates Code P to platform containers, with this edition of the standard combining both pure platforms and flatracks under this letter. Pure platforms bear group code PL or type code P0.



40' platform: 8' wide and 2' high with gooseneck tunnel at both ends

Group code PF covers type codes P1 and P2.

Half-height flats falling under P1, with lateral insertable stanchions

P1 platforms have two complete, fixed end walls, irrespective of how high they are.

Platform containers falling under P2 with corner posts and special load retainers

P2 platforms have fixed posts, either free-standing or with removable top members. The containers illustrated here are specially constructed to accommodate stacking boxes. The boxes are carrying cargo securing materials for securing the containers on board. They are naturally also ideal for transporting other heavy small parts.

Group code PC covers type codes P3 and P4. P3 platforms have folding complete end walls.

40' platform with completely folding end walls - collapsed

40' platform with completely folding end walls

P4 platforms have folding posts, either free-standing or with removable top members.

20' platform with folding free-standing corner posts - folded down in pairs

Group code PS covers type codes P5 to P9. P5 platforms are open at the top and ends (skeletal).

Frames for suspension of clip-on units

In the January 1996 edition, type codes P6 to P9 had not been assigned, but were kept as spares. Here is an example of how one of these codes has been assigned by Hapag-Lloyd:

40' x 8' x 9'6" P8 platform

Detail of P8 platform

40' collapsible flatrack with overheight, collapsible end walls

Coil container with folding end walls

Coil containers are built like flats or flatracks, i.e. they consist of a container floor and flat or frame-like end walls. The container floor has cargo troughs for accommodating coils/rolls of steel sheet. Cargo securing costs are lower, since less complex lashing and blocking is required than on/in normal containers. However, when overall transport costs, including the return transport of empty coil containers, are taken into account, normal carriage without a special container may be more economical. Coil containers could be included amongst named cargo containers, but they are not covered by the standard.

20' flatracks, with fold-down end walls and coil wells (coil containers)

Tank containers are provided for carrying liquids and gases. The characteristics of the substances to be carried determine the material of which the tank is made, while the pressure under which the cargo has to be transported influences its construction. Tank containers almost always have as their basis a steel frame, into which tanks of various shapes may be inserted. Various fittings and accessories are incorporated, depending on type and method of filling and emptying. Temperature-controlled tank containers require special heating or cooling devices. They may be filled via domes or tubes and emptied downwards via floor drains or upwards via riser pipes and pressure generators or in any other suitable manner. The products to be carried may be any types of liquid, liquefied or gaseous substance, ranging from harmless to very dangerous.

Tank containers for non-dangerous liquids come under group code TN. Type codes T0, T1 and T2 distinguish between minimum pressures of 45 kPa, 150 kPa and 265 kPa.

Tank container for non-dangerous liquids

Tank containers intended for liquid foodstuffs must be clearly marked as being intended for this purpose:

Potable liquids only

Half-height tank containers or **half-height liquid containers** serve to carry high-density liquids which cannot be carried in normal tank containers because they cannot be filled to a high enough level and are therefore subject to surging.

Half-height liquid container

Tank containers for dangerous liquids come under group code TD. Type codes T3, T4, T5 and T6 distinguish between minimum pressures of 150 kPa, 265 kPa, 400 kPa and 600 kPa.

Tank containers for carrying dangerous liquids

Such containers are subject, among other things, to the regulations governing the carriage of hazardous materials and may also have to be tested for compliance with the regulations of the Department of Transportation (DOT) or the German Federal Institute for Materials Research and Testing (BAM).

20' x 8'6" tank container for hazardous materials with a test pressure of 600 kPa

Tank containers for gases are assigned to group code TG and type codes T7, T8 and T9. T7 and T8 cover minimum pressures of 910 kPa and 2,200 kPa, while T9 does not as yet have a pressure assigned to it.

Tank containers must be at least 80% full for safety reasons, so as to prevent dangerous surging of the liquids in transit. As a rule of thumb, they should not be filled more than 95% full, so as to allow for thermal expansion of the contents.

The CTU packing guidelines state under the heading "Scope":

> *... They do not cover the filling or emptying of tank containers, portable tanks, or road tank vehicles, or the transport of any bulky cargo in bulk packagings.*

For this reason, nothing more will be stated with regard to tank containers at this point in the Handbook.

Tank containers may be replaced by introducing "flexible tubes" into standard containers, so turning them into temporary tank containers. However, a major problem associated with this is surging of the liquids, which may result in damage to the container walls.

Frequently used terms and comments:

Closed containers include all non-ventilatable general purpose, dry bulk and tank containers. These containers allow no or only very slight air exchange. They are consequently gas-tight or at any rate virtually gas-tight. They are not suited to transporting goods which require an exchange of gases.

The phrase **design for ease of opening** is found in container literature in relation to the desire for rapid packing and unpacking. It is often used in relation to dry bulk containers with special openings.

Half-height containers are lower than standard containers. The size codes distinguish between those 1,295 mm (4'3") high and those of a height less than or equal to 1,219 mm (4'). The containers are specially designed for goods with low stowage factors and for high-density cargoes, such as heavy barrels, metal sheet etc.

The following needs to be said with regard to **special containers**: from a technical point of view, these meet the needs of many forwarders and are desirable with regard to cargo securing. Their special fittings simplify packing and cargo securing, reducing securing costs and shipping risks. However, since they are adapted to one product or group of products to be transported, it is more difficult to use them on all routes, resulting in higher freight rates than for standard containers due to more frequent carriage of empty containers. From the point of view of cargo safety, however, special containers developed for a particular product are preferable to conventional containers.

All wooden parts of containers traveling to Australia and New Zealand, including packaging and securing lumber, must be treated, and proof must be provided in the form of appropriate wood treatment certificates. The wooden parts of most containers are impregnated against insect infestation. Australia's and New Zealand's quarantine regulations require proof in the form of a plate:

TREATED AGAINST SIREX

This provides documentary evidence that the wooden parts have been treated against the Sirex wasp.

3.1.2 CSC & structural and testing regulations

The technical requirements placed on containers are enshrined in the respective standards and in the "International Convention for Safe Containers" or "CSC".

The aim of the Convention is to achieve the highest possible level of safety of human life in the handling, stacking and transporting of containers. The Convention applies to all containers used for international transport, except containers developed especially for air travel.

Article III, entitled "Application" states:

> *2. Each new container shall be approved either in accordance with the provisions for type-testing or for individual testing as contained in Annex I.*

The Convention specifies precise requirements which individual components must meet. Annex II of the CSC gives examples of structural safety requirements and tests. According to the CSC,

> *a container made from any suitable material which satisfactorily performs the following tests without sustaining any permanent deformation or abnormality which would render it incapable of being used for its designed purpose, shall be considered safe. ...*

Every contracting state must ensure that effective procedures are put in place to enforce the regulations in Annex I of the Convention. This Annex sets out regulations for the testing, inspection, approval and maintenance of containers. However, the text of the Convention does allow duly authorized organizations to be entrusted with all these tasks, other than maintenance. In many countries, the national classification societies are entrusted with these tasks, e.g. Germanischer Lloyd in Germany.

A Safety Approval Plate must be permanently affixed to every container at a readily visible place, where it cannot be easily damaged.

CSC plate

The Plate shall contain the following information in at least the English or French language:

- "CSC SAFETY APPROVAL"
- Country of approval and approval reference
- Date (month and year) of manufacture
- Manufacturer's identification number of the container or, in the case of existing containers for which that number is unknown, the number allotted by the Administration
- Maximum gross weight (kilograms and lbs)
- Allowable stacking weight for 1.8 g (kilograms and lbs)
- Transverse racking test load value

The Safety Approval Plate (...) shall take the form of a permanent, non-corrosive, fire-proof rectangular plate measuring not less than 200 mm by 100 mm. The words "CSC Safety Approval" of a minimum letter height of 8 mm and all other words and numbers of a minimum height of 5 mm shall be stamped into, embossed on or indicated on its surface in any other permanent and legible way.

- Country of Approval and Approval Reference is in this case the USA, the certifier is AB, standing for the American Bureau of Shipping, the reference is 745.

Test plate from American Bureau of Shipping

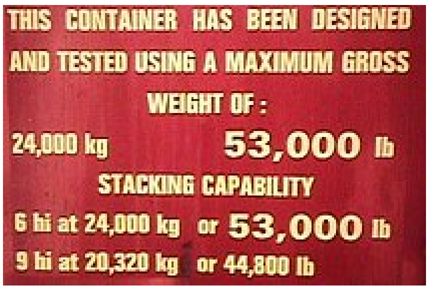
- Date (month and year) of manufacture is year: 1998 and month: September (stated according to ISO standard as 98-9).

- Manufacturer's identification number of the container is JDK ...and so on.

- Maximum gross weight (kilograms and lbs is stated as 24,000 KGS and 52,910 LBS (i.e. pounds). According to the original DIN/ISO standards, the maximum total mass for a 20' container is 20,320 kg. In the example it is therefore higher. This is no longer the case. As can be seen in the picture to the right, containers with a markedly higher total weight are available.

- Allowable stacking weight for 1.8 g (kilograms and lbs). According to ISO standards, fully loaded containers must be stackable six high. The container given by way of example may be stacked 192,000 high (192,000 kg ÷ 24,000 kg = 8).

These days, higher permissible loading capacities are practically the rule. On many containers, this is not only pointed out on the CSC plate but is also highlighted by the provision of special plates.



- <u>Transverse racking test load value.</u>In this instance, this value is 15,240 KGS or 33,600 LBS.

Transverse racking test

The values stated for the racking test are approximately in line with the standard; if the stated units of mass (kilograms) are converted into newtons, a slight difference remains.

The longitudinal racking test value is not stated on the CSC plate.

Longitudinal racking test

The test must be performed from both sides. The ISO standard requires loading of only 75 kN, Lloyd's Register requires 100 kN and Germanischer Lloyd applies 125 kN in its tests.

If important, legally prescribed data are no longer visible, a complaint should be lodged.

Damaged Safety Approval Plate

CSC plate

... The country of Approval should be indicated by means of the distinguishing sign used to indicate country of registration of motor vehicles in international road traffic. ...

The F in the above example stands for France. BV is the abbreviation for the classification society Bureau Veritas, which operates in France.

Test plate from Bureau Veritas

Paragraph 2 b) states):

A blank space should be reserved on the Plate for insertion of end and/or side-wall strength values (factors) in accordance with Regulation 1, paragraph 3 and Annex II, texts 6 and 7. A blank space should also be reserved on the Plate for first and subsequent maintenance examination dates (month and year) when used.

The CSC Safety Approval Plates illustrated above do not carry these details. With good reason, since the regulations subsequently state:

End Wall Strength to be indicated on plate only if end walls are designed to withstand a load of less or greater than 0.4 times the maximum permissible payload, i.e. 0.4 P.
Side Wall Strength to be indicated on plate only if the side walls are designed to withstand a load of less or greater than 0.6 times the maximum permissible payload, i.e. 0.6 P.

This is based on Paragraph 3 of Regulation 1, which states:

Where the Administration considers that a new container satisfies the requirements of the present Convention in respect of safety and if, for such container, the end and/or side-wall strength value (factor) are designed to be greater or less than that stipulated in Annex II such value shall be indicated on the Safety Approval Plate.

Positioning of data on the Safety Approval Plate

"A blank space should also be reserved on the CSC Plate for first and subsequent maintenance examination dates (month and year) when used."

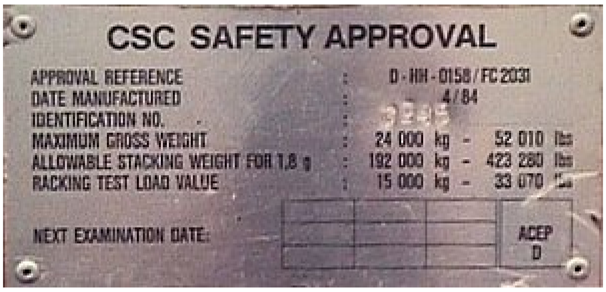
In the example illustrated, this blank space has been left not at the bottom but on the right of the other required data (see arrow). This is common practice.

In the "International Convention for Safe Containers", Regulation 2 of Annex I deals with maintenance, and reads as follows:

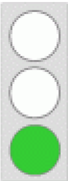
1. *The owner of the container shall be responsible for maintaining it in safe condition.*

2. *The owner of an approved container shall examine the container or have it examined in accordance with the procedure either prescribed or approved by the Contracting Party concerned, at intervals appropriate to operation conditions. The date (month and year) before which a new container shall undergo its first examination shall be marked on the Safety Approval Plate.*

3. *The date (month and year) before which the container shall be re-examined shall be clearly marked on the container on or as close as practicable to the Safety Approval Plate and in a manner acceptable to that Contracting Party which prescribed or approved the particular maintenance procedure involved.*

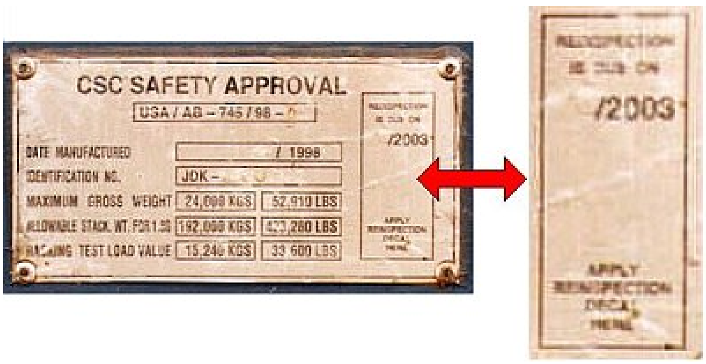


Next examination date not stated



Correct: Next examination date entered

4. *The interval from the date of manufacture to the date of the first examination shall not exceed five years. Subsequent examination of new containers and re-examination of existing containers shall be at intervals of not more than twenty-four months. All examinations shall determine whether the container has any defects which could place any person in danger.*



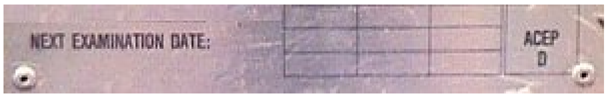
Correct: Interval between date of manufacture and first examination amounts to 5 years

The container was manufactured in 1998. On the CSC Plate, the first re-examination date is given as being month 09, i.e. September, 2003 (this is difficult to read on the Figure).

5. *For the purposes of this Regulation, "the Contracting Party concerned" is the Contracting Party of the territory in which the owner is domiciled or has his head office.*

For some years now, owners have in most cases been responsible for examining their own containers. Regulators have provided for this by establishing an "**A**pproved **C**ontinuous **E**xamination **P**rogram", in which owners participate. **ACEP** is a recognized repair and maintenance system providing for regular examinations and servicing. To participate actively in this program, it is necessary to register with the competent authorities. Registration is indicated on the container. The owner has then to take responsibility for the necessary inspections and the date for re-examination need no longer be indicated on the CSC plate.

A valid ACEP renders it unnecessary to indicate a next examination date.



"Approved Continuous Examination Program" registration data

Most container owners participate in the ACEP.

Chapter II of the "International Convention for Safe Containers" sets out regulations for approval of new containers by design type, as quoted in detail below:

Regulation 3 - Approval of new containers

To qualify for approval for safety purposes under the present Convention all new containers shall comply with the requirements set out in Annex II.

Regulation 4 - Design type approval

In the case of containers for which an application for approval has been submitted, the Administration will examine designs and witness testing of a prototype container to ensure that the containers will conform with the requirements set out in Annex II. When satisfied, the Administration shall notify the applicant in writing that the container meets the requirements of the present Convention and this notification shall entitle the manufacturer to affix the Safety Approval Plate to every container of the design type series.

Regulation 5 sets out the provisions for approval by design type:

1. *Where the containers are to be manufactured by design type series, application made to an Administration for approval by design type shall be accompanied by drawings, a design specification of the type of container to be approved, and such other data as may be required by the Administration.*
2. *The applicant shall state the identification symbols which will be assigned by the manufacturer to the type of container to which the application for approval relates.*
3. *The application shall also be accompanied by an assurance from the manufacturer that he shall:*
   - *a) produce to the Administration such containers of the design type concerned as the Administration may wish to examine;*
   - *b) advise the Administration of any change in the design or specification and await its approval before affixing the Safety Approval Plate to the container;*
   - *c) affix the Safety Approval Plate to each container in the design type series and to no others;*
   - *d) keep a record of containers manufactured to the approved design type. This record shall at least contain the manufacturer's identification numbers, dates of delivery and names and addresses of customers to whom the containers are delivered.*
4. *Approval may be granted by the Administration to containers manufactured as modifications of an approved design type if the Administration is satisfied that the modifications do not affect the validity of tests conducted in the course of design type approval.*
5. *The Administration shall not confer on a manufacturer authority to affix Safety Approval Plates on the basis of design type approval unless satisfied that the manufacturer has instituted internal production-control features to ensure that the containers produced will conform to the approved prototype.*

Regulation 6 relates to "Examination during production":

In order to ensure that containers of the same design type series are manufactured to the approved design, the Administration shall examine or test as many units as it considers necessary, at any stage during production of the design type series concerned.

Regulation 7 covers "Notification of Administration":

The manufacturer shall notify the Administration prior to commencement of production of each new series of containers to be manufactured in accordance with an approved design type.

Chapter III of the CSC sets out "Regulations for approval of new containers by individual approval" and chapter IV sets out "Regulations for approval of existing containers".

In Germany, Germanischer Lloyd is the "administration" responsible for type testing of containers. Containers are certified if they fulfill the requirements of Annex II with regard to "Structural safety requirements and tests" and of course the other standards to be complied with.

Germanischer Lloyd

Typ-Zertifikat für Container

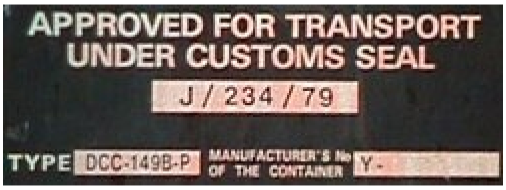
In the case of box containers, the test plate is generally affixed to the left door leaf.

Germanischer Lloyd test plates for approval by design type

The classification societies mentioned above are just a few examples of the many in existence. Other examples are the Belgian Bureau Veritas, Lloyd's Register in Great Britain, Nippon Kaiji Kyokai in Japan and Det Norske Veritas in Norway.

The Figures show additional plates affixed to the container and/or markings written thereon. In the "International Convention for Safe Containers", Regulation 1, Point 4 comments on this issue as follows:

> *4. The presence of the Safety Approval Plate does not remove the necessity of displaying such labels or other information as may be required by other regulations which may be in force.*



An international customs agreement ensures that empty containers do not count as imported merchandise in member states and are thus free of duty provided that the containers remain only temporarily in the customs territory. In addition, the container itself is deemed to be a bonded space.

Type test approval, Germanischer Lloyd

Although this container was manufactured in China for an owner in Bermuda, it was certified by Germanischer Lloyd. Of interest is the fact that Great Britain is the country of registration of participation in an "**A**pproved **C**ontainer **E**xamination **P**rogram" (ACEP) - a clear demonstration of the globalization of container traffic.

Container certified by Germanischer Lloyd (GL) with British ACEP

Container certified by Bureau Veritas (BV) with American ACEP

The various contracting states each recognize one another's national approving bodies. Although the states are bound by the CSC's structural safety requirements and tests, there is nothing to stop them enforcing additional safety requirements for their own containers.

Type testing involves a wide range of test procedures, covering, for example, lifting from top corner castings, lifting from bottom corner castings, lifting using other additional devices on the container such as forklift pockets, grappler arm positions and other methods. The test procedures also extend to stacking and to concentrated loads on roof and floor. Transverse racking is another aspect which is subject to testing. Furthermore, containers must undergo permissible loading capacity tests with regard to longitudinal restraint, the end walls and the side walls.

The introduction to "Structural safety requirements and tests" reads as follows:

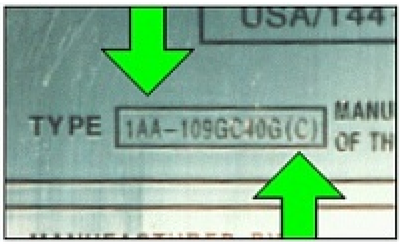
In setting the requirements of this Annex, it is implicit that in all phases of the operation of containers the forces as a result of motion, location, stacking and weight of the loaded container and external forces will not exceed the design strength of the container. In particular, the following assumptions have been made:

a) the container will so be restrained that it is not subjected to forces in excess of those for which it has been designed;

b) the container will have its cargo stowed in accordance with the recommended practices of the trade so that the cargo does not impose upon the container forces in excess of those for which it has been designed.

This is significant in relation to the later Sections about packing of containers and cargo securing. Only if containers are selected in accordance with the cargo to be carried and properly packed are they in a position to justify the trust placed in them.

Testing and certification always relate to a particular type. A valid CSC plate affixed to a particular container tells the user what type of container he has before him. Nonetheless, some CSC plates give further details about this and about other supplementary standards:



Selective enlargement on the left

The character combination 1AA indicates a 40' long, 8'6" high standard container, while the letter C here stands for Closed.

Selective enlargement on the right

This container has also been type tested (yellow arrow). The character combination 1AA indicates a 40' long ISO container 8'6" high. The abbreviation OT stands for open-top (green arrow). The container is not subject to an "**A**pproved **C**ontainer **E**xamination **P**rogram" (ACEP) and the Plate therefore carries the date of its next examination (blue arrow), fully in accordance with regulations. Since the container was built in 1997, its first test falls due in 2002, with subsequent examinations at two year intervals.

3.1.3 Cargo securing equipment

Owing to their cargo space being closed on all sides, box containers offer good possibilities for cargo securing by compact loading.

For securing individual items, a tight fit may be achieved using bracing, especially in corrugated steel containers. On the other hand, the possibilities for lashing are very limited. Relatively useful lashing lugs or rings are provided in all inland containers. Problems arise if lashing points are overstowed and are no longer available or reachable. Their strength also presents a problem: in general, their Maximum Securing Load (MSL) or Lashing Capacity (LC) is only 1,000 daN per lashing point.

Lashing points on the frame parts of a container

The lashing points for containers are not currently covered by standards and may therefore differ greatly. Not all lashing points may be loaded in all directions.

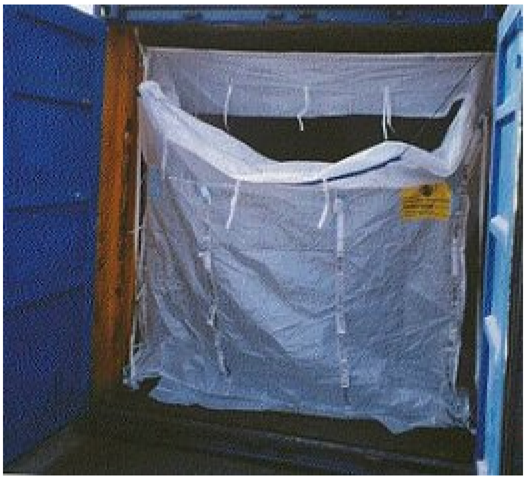
Lashing bars on the corner posts in the door area

Lashing points must be attached to the frame parts of a container, since only these components are adequately capable of absorbing forces.

"Lugs" in the area of the top side rails/ top side rails

Lugs fitted in the area of the top side rails and sometimes also the front top end rails can only be used to a minimal degree for traditional cargo securing by lashing. Lugs are suitable, indeed almost too strong, for attaching "inlets" or special nonwoven fabric for catching sweat.

Nonwoven fabric providing protection against condensation water



Attaching nonwoven fabric

In any case, such measures serve to protect the cargo, and therefore to keep it safe: nonwoven fabrics provide protection against moisture or wetness dripping from the container ceiling and "inlets" protect against contact with the container walls. Some containers have lashing bars halfway up the container walls. In corrugated steel containers, they are welded in between the corrugations. The maximum securing load of these bars is not very high and they can only be used to secure relatively light individual items or small blocks of palletized cargo. The same applies to individual lashing rails fitted into the wooden linings of aluminum containers.

Platform containers, i.e. the group comprising platforms and flatracks, have a relatively large number of reasonably strong securing elements.

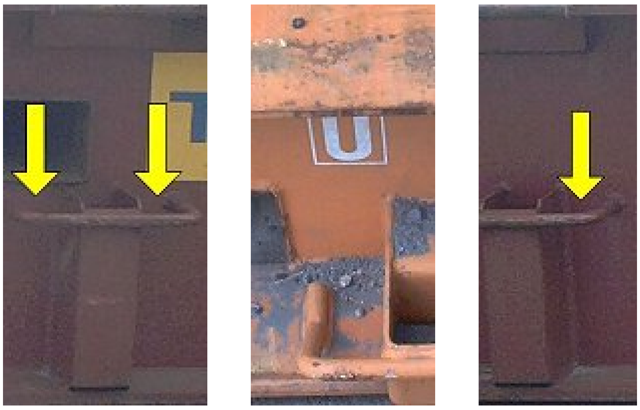
Stanchion pocket in a 40' collapsible flatrack

To achieve a tight fit by application of pressure, stanchions or stakes are very often provided, which may be inserted into corresponding stanchion (or stake) pockets.

Right and left:

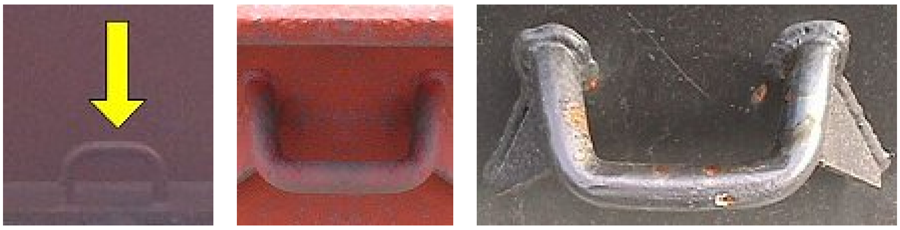
Do not attach lashings to stanchion (or stake) pocket components

Although the stanchion (or stake) pocket closing bar looks suitable for use as a lashing bar, this is expressly forbidden.

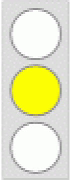


Lashing points next to stanchion pockets on flatracks

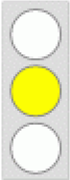
Flatrack with lashing rings



Lashing point on the bottom rail of a flatrack



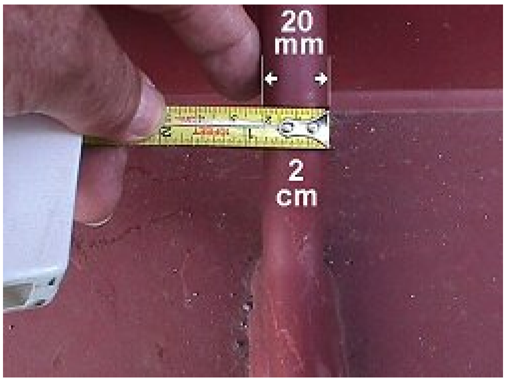
Safe Working Load



Maximum Pull Strength

It is regrettably often the case that no details are given about the strength of lashing points. Even if information is provided, it is mostly of no practical use because of the wording chosen. Further explanations relating to this problem are provided in the section headed Lashing materials, which states:

The maximum securing load (MSL) can be calculated using a rule of thumb, according to which the diameter of the lashing points is determined, squared and multiplied by 10; i.e. diameter x diameter x 10. The result of the calculation is in decanewtons (daN) if the diameter is stated in millimeters and kilonewtons (kN) if the diameter is stated in centimeters.



Determining the maximum securing load of lashing points using rule of thumb method

According to the above-stated rule of thumb, the maximum securing load of the lashing point is determined as follows:

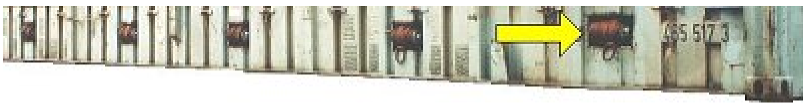
In decanewtons: $20 \cdot 20 \cdot 10 = 4{,}000$ daN

In kilonewtons: $2 \cdot 2 \cdot 10 = 40$ kN

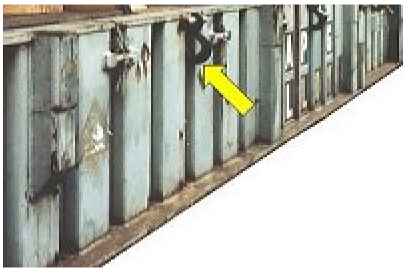
The rule of thumb can only be applied if the weld seams look good and the weld substrate appears sufficiently strong. If lashing points are welded to excessively thin metal sheet, the rule of thumb must not be used for calculation.

The rule cannot be applied, either, if the lashing points, e.g. rings, are held on with pop rivets, thin screws or the like, despite the rings "looking good".

Some platform containers have special securing systems:



Integral belt system in a 40' flatrack - one side ...



... and the other side

This flatrack has fixed belt reels, all on one side. The eyelets of the textile belts can be secured on hooks on the other side. Unfortunately, this securing system is virtually unusable, because the "tie-down lashing/over-top lashing/friction loop" method has only a frictional effect, and this only with one-sided, uneven pretension. The belts do not allow a homogeneous tight fit to be achieved. If four of the total of eight lashing reels were fitted on each side, appropriate securing could be achieved for many types of goods.

The containers themselves are secured on ships and road and rail vehicles by means of the container corner castings. Appropriate securing systems, such as rods on board ship, twist locks or other lock units etc., may be attached in or to the corner castings, which are also responsible for load transfer if the containers are stacked in ship cell guides.

Securing of a container to a chassis

Occasionally, complaints arise during road-side cargo securing inspections because not all of the lock units have been firmly tightened, when of course they should be. The CTU packing guidelines provide advice on this matter. Section 6.4 states, on the subject of "CTUs on vehicles":

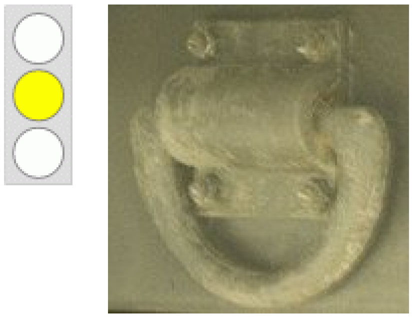
> *6.4.1 CTUs should be firmly secured on vehicles before the vehicle is moved. The most appropriate points for fixing containers and swap-bodies are the bottom corner castings of the unit. Before and during transport, it should be checked that the unit is properly secured on the vehicle.*
> *6.4.2 For transport on public roads or by rail, containers and swap-bodies should be secured to the road or rail vehicle by all bottom corner castings, in the absence of which, appropriate alternative measures should be taken. The main forces during the transport operation should be transferred to the unit through these bottom corner castings. Some additional forces may be transferred between the road vehicle chassis or rail-car surface and the unit bottom through load transfer areas in the unit bottom and in the vehicle surface. The securing devices on the vehicle may be twist locks, securing cones or securing guides. All such securing devices should be designed in such a way that the "open" or "locked" position of such securing devices is readily apparent.*

It is very common for problems to arise when containers, loaded in particular on road vehicles and attached firmly thereto, have to be carried by combined road/ship/road transport. Only occasionally do the vehicles have the legally prescribed lashing points, and even if they are present, they tend to be positioned extremely unfavorably or to be incorrectly or defectively designed. As at 2003, this is true of approx. 80% of all vehicles which have to be carried by sea.

On this matter, Point 2.1.6 of the CTU packing guidelines states:

> *A vehicle should be provided with points for securing it aboard ships (refer to European Standard EN 29367-I (ISO 9367-1): Lashing and securing arrangements on road vehicles for sea transportation on Ro/Ro ships - General requirements - Part 1: Commercial vehicles and combinations of vehicles, semitrailers excluded, and to EN 29367-2 (ISO 9367-2): Lashing and securing arrangements on road vehicles for sea transportation on Ro/Ro ships - General requirements - Part 2: Semitrailers".)*

Strong, well-positioned lashing point on a semitrailer

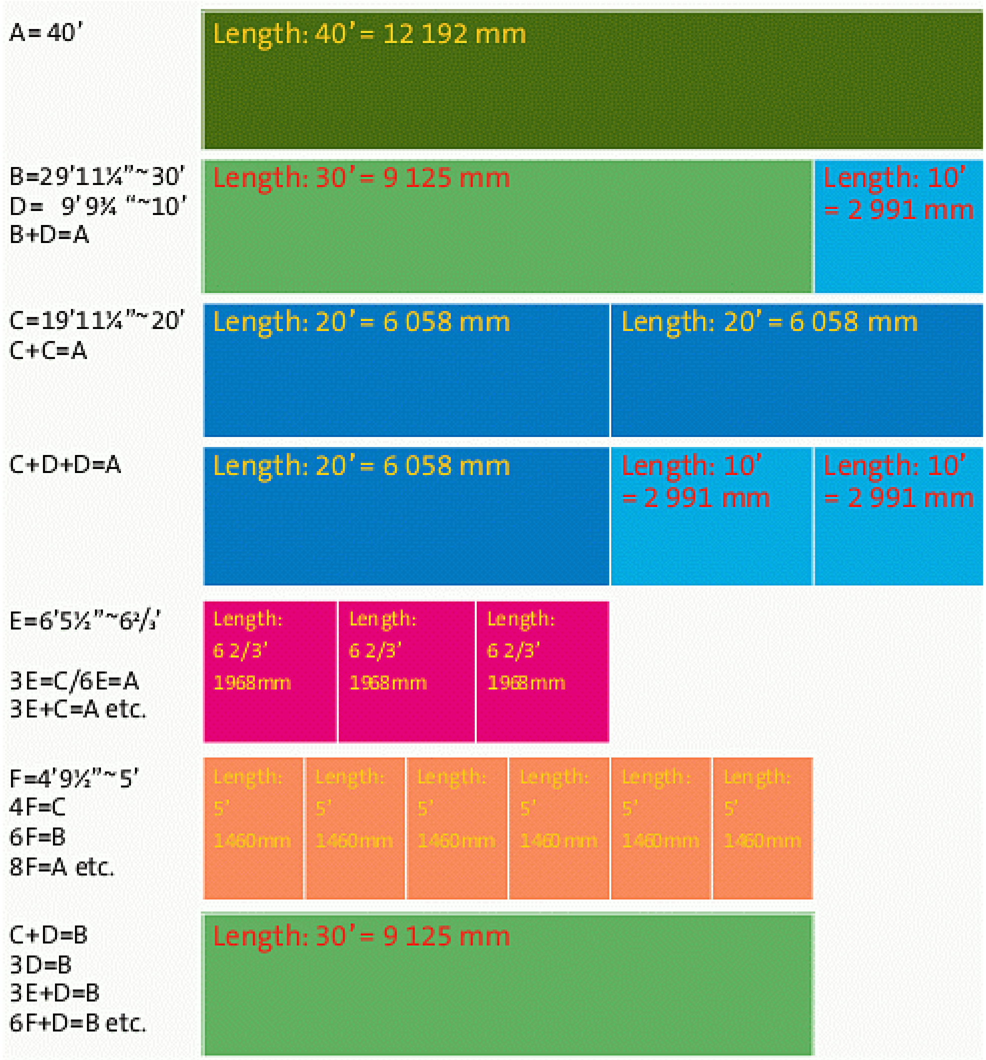


Will the screws withstand the stresses of maritime transport?

Unfavorably located lashing point - unusable

3.2 Container dimensions and weights

The lengths of freight receptacles as were and sometimes still are used for example in inland transport, and of conventional large containers are based on a modular system, for which the starting point was and indeed still is a 40' (12,192 mm) long container. The other nominal sizes have arisen by division, with 3 inches being taken off each time to allow the containers to be combined together in practice.



Example of module combination

Freight containers A, B, C, D etc. are 8' high. If the containers are 8'6" high, the letters are doubled to give AA, BB, CC, DD, for example.

Container dimensions as stipulated in DIN/ISO 668 or DIN 15190, Part 1

Desig-nation	Length			Height			Width			Maximum gross weight	
	mm	ft	in	mm	ft	in	mm	ft	in	kg	lb
1A	12,192	40		2,438	8		2,438	8		30,480	67,200
1AA	12,192	40		2,591	8	6	2,438	8		30,480	67,200
1B	9,125	29	11¼	2,438	8		2,438	8		25,400	56,000
1BB	9,125	29	11¼	2,591	8	6	2,438	8		25,400	56,000
1C	6,058	19	11¼	2,438	8		2,438	8		20,320	44,800
1CC	6,058	19	11¼	2,591	8	6	2,438	8		20,320	44,800
1D	2,991	9	9¾	2,438	8		2,438	8		10,160	22,400
1E	1,968	6	5½	2,438	8		2,438	8		7,110	15,700
1F	1,460	4	9½	2,438	8		2,438	8		5,080	11,200

At the moment, the following lengths are stated and defined in the metric and/or English customary systems. They relate not only to freight receptacles such as containers but also to swap-bodies:

Length code (character)	Container length		
	mm	Feet / ft / '	Inches / in / "
1	2,991	10	
2	6,058	20	
3	9,125	30	
4	12,192	40	
A	7,150		
B	7,315	24	
C	7,430		
D	7,450	24	6
E	7,820		
F	8,100		
G	12,500	41	
H	13,106	43	
K	13,600		
L	13,716	45	
M	14,630	48	
N	14,935	49	
P	16,154		
USA only		53	
Permitted in some states of the USA		57	

Current widths are:

Container width		
mm	Feet / ft / '	Inches / in / "
2,438	8'	
2,500		
2,550		
	8'	6"

Containers of the following heights are in use:

Height code [example of container type]	Container length		
	mm	Feet / ft / '	Inches / in / "
9 [20' Platform]	337	1	1 1/4
9 [40' Platform]	610	2	
9	1,219	4	
8 [Half-Height]	1,293	4	3
0	2,438	8	
2 [Most containers]	2,591	8	6
4	2,743	9	
5 [High Cube]	2,895	9	6
6	> 2,895	> 9	6

Length: 7.43 m
Width : 2.50 m
Height : 2.60 m

Containers 7.43 m long are in principle half-size 49' containers. With a width of 2.50 m and a height of 2.60 m, such containers fulfill the technical requirements and traffic laws of many countries.

Containers suitable for international use

Length: 7.45 m
> Width : 2.55 m
Height : 2.90 m

Proposed size unacceptable in the majority of cases

The above-mentioned container is virtually identical to the CEN standard C-type swap-body, which is 7.45 m long. However, attempts to introduce such a container with widths of over 2.55 m and heights of over 2.90 m may well meet with resistance.

Length = 49' = 14 935.2 mm (14.90 m)
Width = 8'6" = 2 590.8 mm (2.60 m)

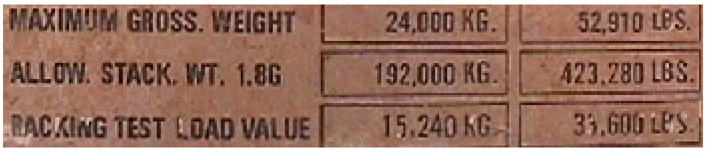
Container used mainly in the USA

The appropriate specialist committees have devoted time to discussing the introduction of 49'/14.9 m long containers with a width of 8' 6"/2.60 m. However, such a container is unacceptable to most of the countries in Africa, Asia, Australasia and Europe. The same applies to a half-length container 24'4½"/7.43 m long, because of the 2.60 m width.

Container size	Maximum gross weight		Regulatory text
	Kilograms (kg)	Pounds (lb)	
20'	20,320	44,800	to old ISO standard
20'	24,000	52,910	to ISO 688
20'	30,480	67,200	optional
30'	25,400		
40'	30,480	67,200	
40'	32,000	70,550	optional

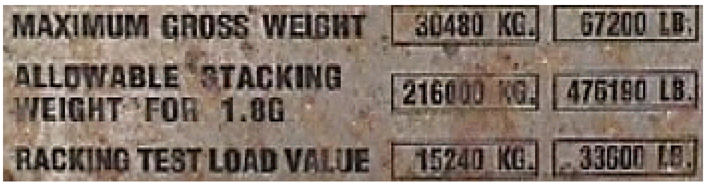
Maximum mass for a 20' container according to the old standard

The significant feature of this container is that the term used is the more correct "mass", the unit of mass being correctly stated as the kilogram.



Maximum mass for a 20' container according to DIN ISO 688

The term used in this example is weight, as is more usual, but the unit used is that of mass. The correct unit would be the newton. The correct unit would be the newton, with the decanewton or kilonewton [daN, kN] also being possible.



Maximum mass for a 40' container according to the old standard or optionally for a more recent 20'

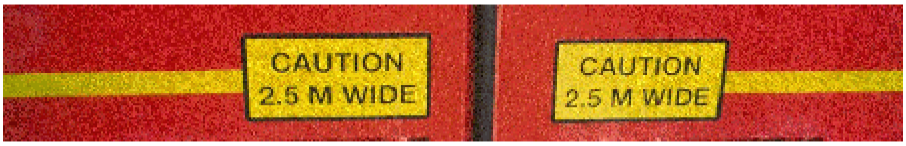
The external dimensions of the containers are specified in ISO 668, with the maximum allowable dimensional tolerances being ± 10 mm. The internal dimensions are stated as minimum values. The current internal container dimensions are dependent on the structural material used and the container type selected.

Standard dimensions	Length		Width	Height	
	20'-Container	40'-Container			
External: mm	6,058	12,192	2,438	2,438	2,591
External: '/"	19' 10 1/2"	40'	8'	8'	8' 6"
Internal: mm	5,867	11,998	2,330	2,197	2,350
Internal: '/"	19' 3"	39' 4 3/8 "	7' 7 3/4"	7' 2 1/2"	7' 8 1/2"
Door opening: mm	Not applicable	Not applicable	2,286	2,134	2,261
Door opening: '/"	Not applicable	Not applicable	7' 6"	7'	

Many of the following statements fall equally within the scope of the operational markings covered in Section 3.5, where additional information may be found.

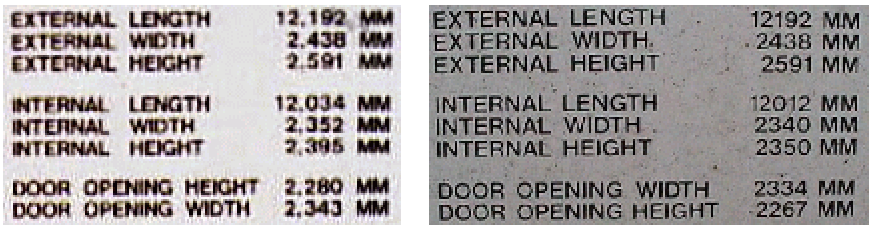
If real data relating to containers to be ordered and subsequently packed are required for the purpose of forward planning, it is best to refer to the brochures published by shipping companies or other container owners. When packing a container, it is important to cast an eye over the plates affixed to it.

Pallet-compatible containers are 2.50 m wide, for example, and usually carry an appropriate warning:

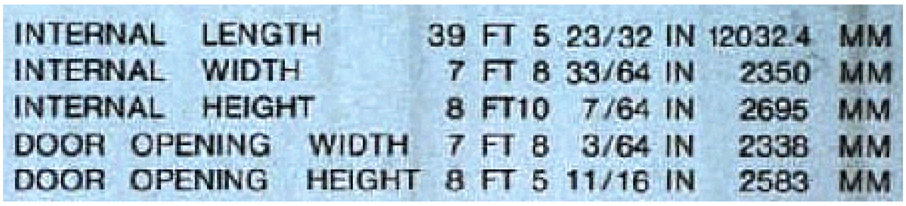


Warning affixed to a 2.5 m wide container

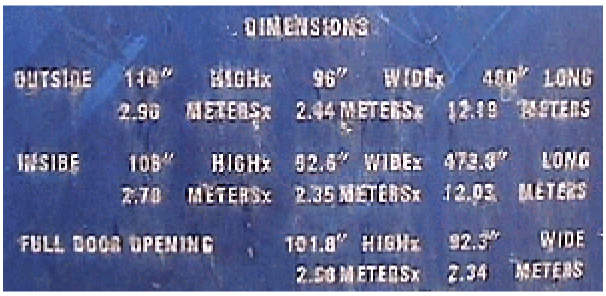
This warning also counts as an operational marking. More detailed information is also to be found in this section.



External, internal and door dimensions, metric system



Internal and door dimensions, in both feet and inches and millimeters Millimeters



Dimensions, stated solely in inches and meters

The following two tables give the lengths and gross weights for 20', 30' and 40' ISO containers and 10' to 40' inland containers.

Container size in feet	Length		Maximum gross weight in kg
	External	Internal	
20'	6,058 mm	5,867 mm	20,320
30'	9,125 mm	8,931 mm	25,400
40'	12,192 mm	11,998 mm	30,480

20' container with maximum total weight of 30,480 kilograms

The ISO standard maximum gross weights for inland containers are specified as follows:

Length in feet	Length in millimeters	Width in millimeters	Gross weight [kg]
10'	2,991	2,500	10,000
20'	6,058	2,500	20,000
30'	9,125	2,500	25,000
40'	12,192	2,500	30,000

The minimum dimensions for the loading areas and volumes of ISO containers are specified as follows:

Container size	Designation	Loading area [m^2]	Volume [m^3]
40'	1 AA	28.0	65.7
40'	1 A	28.0	61.4
20'	1 CC	13.7	32.1
20'	1 C	13.7	30.0

Data relating to loading areas are very seldom found. Volumes, on the other hand, are almost always stated:

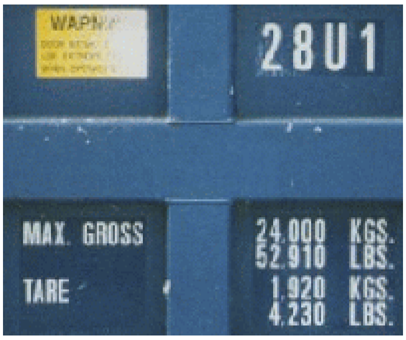
As a rough guide, values are approx. 30 m³ for 20' containers and approx. 67 m³ for 40' containers.

For tank containers, preferred practice is to state their volume in liters rather than in cubic meters:

Volume in liters on a French tank container

As already described in Section 3.1.2 CSC & structural and testing regulations, the International Convention for Safe Containers specifies that the maximum gross weight must be marked on the CSC plate. Other regulations require the maximum gross weight and the tare weight to be indicated. This constitutes the minimum information with which

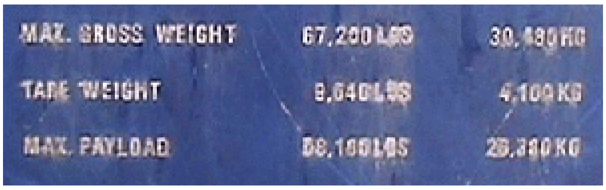
the user of the container must be provided by law.



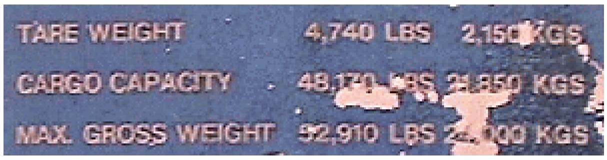
Minimum information on a half-height open-top

The maximum payload can be calculated as the difference between the maximum gross weight and the tare weight, but this information is already indicated on most containers.

Of interest in this context are the different terms selected by the various container owners. It would be altogether desirable if these terms were to be standardized.



Maximum gross weight - tare weight = permissible payload



Tare weight + permissible payload = maximum gross weight

On platform containers, the data are located on the end walls or frame parts.

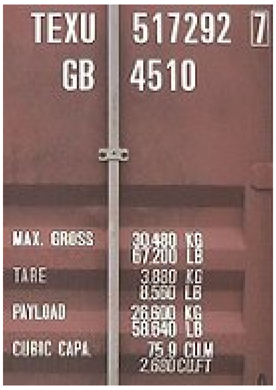
Markings on platform containers, including weights and other data


Max Gross 45,000 kg
or 99,210 lb
Tare 5,700 kg
or 12,570 lb

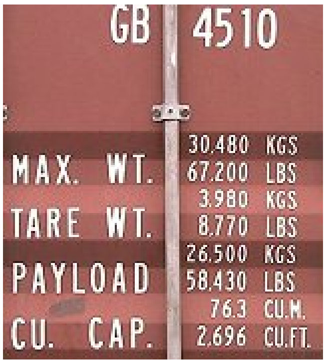
Markings on a collapsible flatrack with a 45,000 kg maximum weight

Volumes are almost always to be found together with the weight information. On box containers, all the above-

mentioned values are usually marked large and clear on the right door leaf.



Weights and volumes on 20' reefers and 40' general purpose containers



Weights and volumes on high-cube reefers and general purpose containers

Nothing should be stuck over these important data on a container:

The text of the sticker refers limited quantities of hazardous materials and has nothing to do with the maximum gross weight. Loading area and loading capacity (volume) depend principally on wall thickness and structural height.

Unfavorably positioned sticker

In practice, the ISO standard minimum values for weights and volumes are generally exceeded. Depending on the intended goods transport operation, it may therefore be worth making a comparison and choosing the most favorable container. A comparison of the gross stowage factor with the stowage factor of the respective transport receptacles is always appropriate.

Containers often carry information about these aspects (picture to the right).

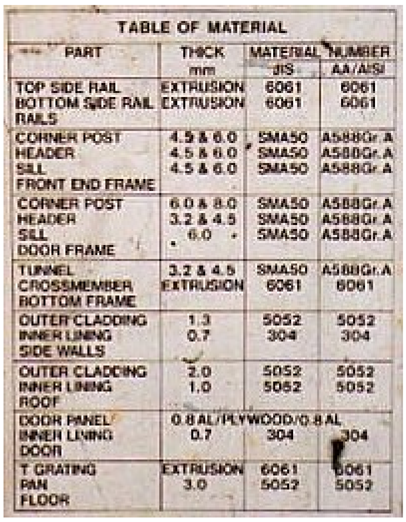
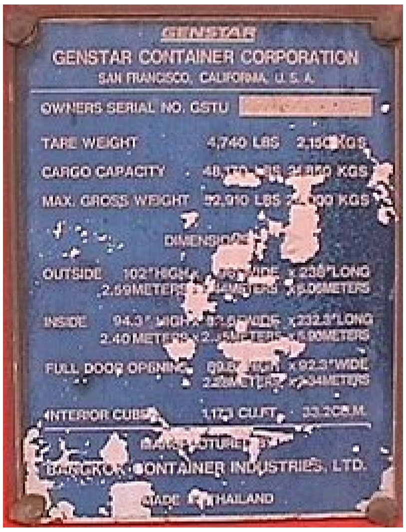


TABLE OF MATERIAL

PART	THICK mm	MATERIAL NUMBER JIS	MATERIAL NUMBER AA/AISI
TOP SIDE RAIL BOTTOM SIDE RAIL RAILS	EXTRUSION EXTRUSION	6061 6061	6061 6061
CORNER POST HEADER SILL FRONT END FRAME	4.5 & 6.0 4.5 & 6.0 4.5 & 6.0	SMA50 SMA50 SMA50	A588Gr.A A588Gr.A A588Gr.A
CORNER POST HEADER SILL DOOR FRAME	6.0 & 8.0 3.2 & 4.5 6.0	SMA50 SMA50 SMA50	A588Gr.A A588Gr.A A588Gr.A
TUNNEL CROSSMEMBER BOTTOM FRAME	3.2 & 4.5 EXTRUSION	SMA50 6061	A588Gr.A 6061
OUTER CLADDING INNER LINING SIDE WALLS	1.3 0.7	5052 304	5052 304
OUTER CLADDING INNER LINING ROOF	2.0 1.0	5052 5052	5052 5052
DOOR PANEL INNER LINING DOOR	0.8 AL/PLYWOOD/0.8 AL 0.7	 304	 304
T GRATING PAN FLOOR	EXTRUSION 3.0	6061 5052	6061 5052

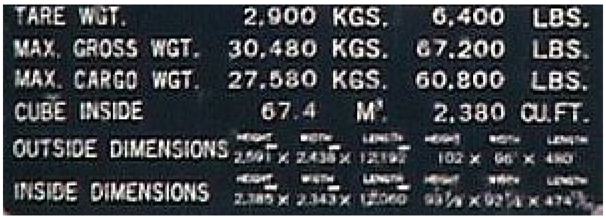
Details of the materials used in a container

Sometimes, data about dimensions, weights, volumes etc. are also given on the CSC plates themselves or on separate plates:



CSC plate giving virtually full information

Separate plate giving virtually full information



Separate plate giving weights and dimensions

An English foot is divided into 12 inches and corresponds to 30.48 cm. An English inch corresponds to 25.4 mm. While inches are conventionally each subdivided into 12 "lines", it is usual to state fractions of an inch, such as ½", ¼", 1/8"or 1/16". An English pound (lb) corresponds to 453.6 g. A cubic foot (cu.ft.) corresponds to 28.35 liters.

Metric units may be roughly converted by rule of thumb into English customary units and vice versa, as follows:

- Meter x 10 ÷ 3 = foot
- Foot ÷ 10 x 3 = meter
- Kilogram x 2 + 10 % = pound
- Pound ÷ 2 - 10 % = kilogram
- Cubic meter x 35 = cubic foot
- Cubic foot ÷ 35 = cubic meter

3.3 Identification system

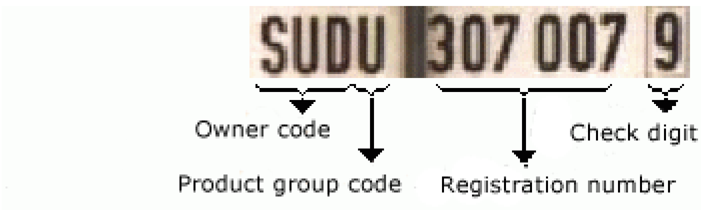
The current standard which deals with the coding, identification and marking of containers is DIN EN ISO 6346, dated January 1996. Among other things, this standard specifies that the previous standards with similar content have equal validity, since a number of older versions of containers with different markings naturally remain in service alongside the brand new ones. This Section will provide only certain essential explanations with regard to the systems used - for more detailed information, the reader should refer to the corresponding standards and more extensive specialist literature.

The foreword to the standard states, among other things, that it includes not only the statutory units but also corresponding sizes stated in Anglo-American units. Under the German Units of Measurement Act, 22nd February 1985, the use of such units nationally and commercially in Germany is proscribed. Such units may only be quoted to aid business relationships with countries which still use these units.

Marking on the door of a container

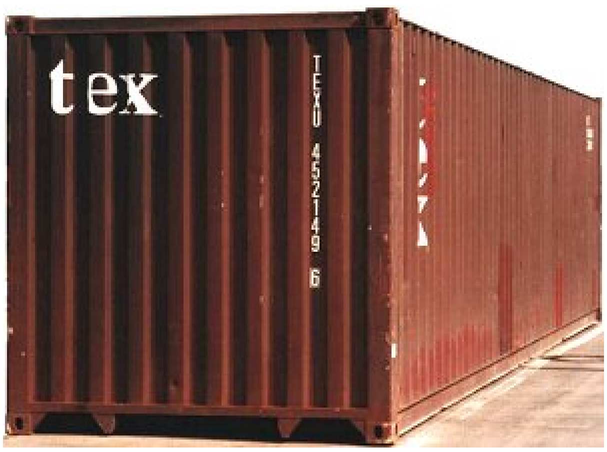
A distinction is drawn between compulsory and optional marking. Compulsory ISO marking must be used on all containers, while optional marking does not have to be: they are included in the standard to improve understanding and to promote uniform application of marking. However, if a particular style of representation is specified for an optional mark, it must be complied with. The terms "compulsory" and "optional" used in the standard do not apply to the requirements of any legislative bodies, however.

The following is a basic version of horizontal container marking.



Container identification marking

This Figure shows a version of vertical container marking.



Marking on the front end of a container

The container identification system specified in DIN EN ISO 6346 consists solely of the elements shown, which can only be used together:

- owner code, consisting of three capital letters
- product group code, consisting of one of capital letters U, J or Z
- six-digit registration number
- check digit

The owner code must be unique and registered with the International Container Bureau (BIC - Bureau International des Containers - 14, Rue Jean Rey, 75015 Paris), either directly or through a national registration organization. The German BIC representative is the Studiengesellschaft für den kombinierten Verkehr e.V., Börsenplatz 1, 60313 Frankfurt am Main (tel. +49 69 283571 or +49 172 6700597). The SGKV can provide information and handle applications for registration of an owner code. In the Figures shown, the owner code consists respectively of the letter combinations SUD and TEX.

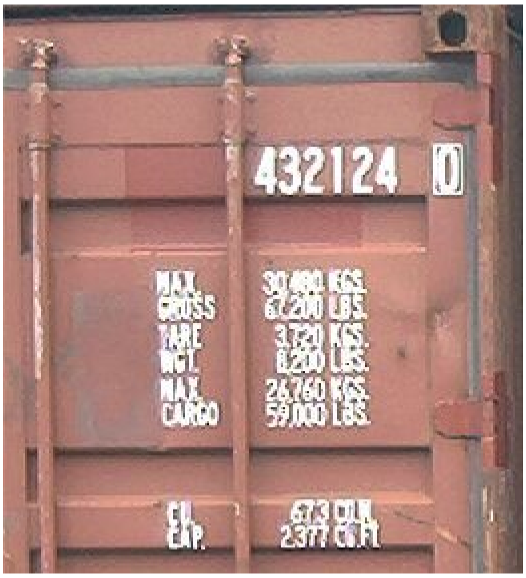
The product group code consists of one of the following three capital letters:

U - for all freight containers

J - for detachable freight container-related equipment

Z - for trailers and chassis

The term owner code may also apply to the combination of owner code and product group code, which is also known as an alpha prefix.



Alpha prefix absent

If the owner code is absent, the container cannot be identified.

The registration or serial number consists of six digits. In the examples shown, these numbers are 307007 and 452149. If the container number consists of fewer than six digits, it is preceded by enough zeros to make a six-digit number sequence.

The check digit, 9 and 6 respectively in the two examples shown, is always a single-digit number. It is usually in a box, to make it stand out from the registration number.

The check digit can be used to validate whether the owner code, product group code and registration number have been accurately transmitted. No freight information system (FIS), transport information system (TIS) or similar data processing system will accept a container number, if the result of the automatic checking procedure does not show agreement with the check digit. The procedure is deliberately designed to ensure that a number of transmission errors cannot cancel one another out, resulting in the acceptance of incorrect data. The checking procedure is as follows:

An equivalent numerical value is assigned to each letter of the alphabet, beginning with 10 for the letter A (11 and multiples thereof are omitted):

A	B	C	D	E	F	G	H	I	J	K	L	M
10	12	13	14	15	16	17	18	19	20	21	23	24

N	O	P	Q	R	S	T	U	V	W	X	Y	Z
25	26	27	28	29	30	31	32	34	35	36	37	38

The individual digits of the registration number keep their everyday value, i.e. 1 = 1, 2 = 2 etc.

The following numerical values are accordingly obtained for the two examples with the alpha prefixes "SUDU" and "TEXU":

S	U	D	U	3	0	7	0	0	7
30	32	14	32	3	0	7	0	0	7

T	E	X	U	4	5	2	1	4	9
31	15	36	32	4	5	2	1	4	9

Each of these numbers is multiplied computationally, as a function of its position, by numerical values of 2^0 to 2^9: the first number by 1, the second by 2, the third by 3 and the 10th by 512.

1st number/ digit	2nd number/ digit	3rd number/ digit	4th number/ digit	5th number/ digit	6th number/ digit	7th number/ digit	8th number/ digit	9th number/ digit	10th number/ digit
2^0	2^1	2^2	2^3	2^4	2^5	2^6	2^7	2^8	2^9
1	2	4	8	16	32	64	128	256	512

The following calculations are performed for the two examples:

S	U	D	U	3	0	7	0	0	7
30	32	14	32	3	0	7	0	0	7
×	×	×	×	×	×	×	×	×	×
1	2	4	8	16	32	64	128	256	512
=	=	=	=	=	=	=	=	=	=
30	64	56	256	48	0	448	0	0	3,584
The sum of these numbers equals				4,486	and is divided by 11, giving				407.8
The integer multiplied by 11 equals				4,477	The difference between the resultant values is the check digit				
				9					

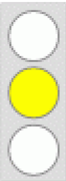
T	E	X	U	4	5	2	1	4	9
31	15	36	32	4	5	2	1	4	9
×	×	×	×	×	×	×	×	×	×
1	2	4	8	16	32	64	128	256	512
=	=	=	=	=	=	=	=	=	=
31	30	144	256	64	160	128	128	1,024	4,608
The sum of these numbers equals				6,573	and is divided by 11, giving				
The integer multiplied by 11 equals				6,567	The difference between the resultant values is the check digit				
				6					

If the check digits 9 and 6 respectively are correctly input in each case during data entry, the system accepts the data.

If someone makes a mistake when transmitting a container number and inputs the alphanumeric sequence TEXU 4521**4**9 into a corresponding system instead of TEXU 4521**5**9, the program would perform the following calculation:

T	E	X	U	4	5	2	1	5	9
31	15	36	32	4	5	2	1	5	9
x	x	x	x	x	x	x	x	x	x
1	2	4	8	16	32	64	128	256	512
=	=	=	=	=	=	=	=	=	=
31	30	144	256	64	160	128	128	1280	4608
The sum of these numbers equals				6,829	and is divided by 11, giving				620.8
The integer multiplied by 11 equals				6,820	The difference between the resultant values is the check digit				
				9					

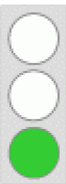
Since the correct check digit for this container is 6, the system would indicate an error.




Disadvantage of check digit 

The check digit 0 may occur twice, since it arises where the final difference is 0 and where it is 10. To ensure that this does not happen, the standard recommends that registration numbers should not be used which produce a final difference of 10. This is the case, however, with the registration number shown.

T	R	L	U		5	4	3	8	6	2	0
31	29	23	32		5	4	3	8	6	2	
1	2	4	8		16	32	64	128	256	512	
31	58	92	256		80	128	192	1,024	1,536	1,024	4,421
4,421	11	401.9	401	11	4,411	10					




Correct identification using check digit 

H	L	X	U		4	6	9	1	9	2	0
18	23	36	32		4	6	9	1	9	2	
1	2	4	8		16	32	64	128	256	512	
18	46	144	256		64	192	576	128	2,304	1,024	4,752
4,752	11	432.0	432	11	4,752	0					

3.4 Size and type codes

The following photo shows a variant of horizontal marking which additionally includes country, size and type codes (in accordance with the 1985 version of DIN ISO 6346, use of which is still permitted):

Container identification including country, size and type codes

Appropriate abbreviations are used for the various countries, here US for United States of America, GB for Great Britain etc.

The first digit of the size code indicates the length of the container, with the number 4 standing for a 40' container. The second digit indicates height and whether or not a gooseneck tunnel is present. In our example, the number 3 stands for a height of 8 foot 6 inches (8'6") with gooseneck tunnel. The first digit of the type code indicates container type. Here, 1 means that the container is a closed container with ventilation openings. The second digit of the type code relates to special features. The 0 used here means opening at the end.

In the associated standard, columns are set out vertically:

Marking on Containers : Size and Type Code			ISO 6346
1	2	3	4
Length	Height	Type	Features

The corresponding data are laid out underneath. The abbreviation g.n.t. stands for gooseneck tunnel. A differently laid out size code summary is shown below:

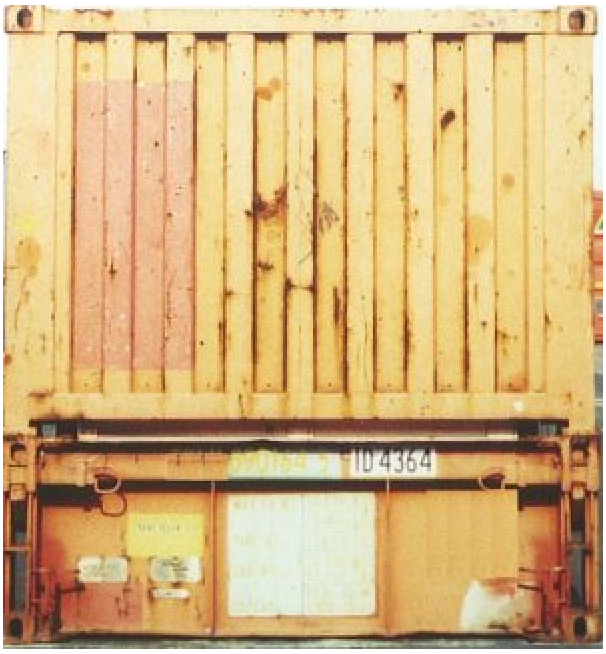
1st digit	The digits have the following meanings...			
Length	1 = 10 '	2 = 20 '	3 = 30 '	4 = 40'

2nd digit	The digits have the following meanings...			
Height	0 = 8'	1 = 8' g.n.t	2 = 8' 6"	3 = 8' 6" g.n.t.
Height	4 = > 8'6"	5 = > 8' 6" g.n.t.	6 = > 4 ' 3 "	7 => 4' 3 "g.n.t.
Height	8 = > 4' 3 "< 8'	9 = < 4'		

In the type code, the first digit (i.e. the 3rd digit overall) indicates the container type and the second (i.e. the 4th digit overall) indicates special features. However, there is a connection between the respective digits, which the following representation is intended to explain:

Marking on Containers : Size and Type code		**ISO 6346**	
1	**2**	**3**	**4**
Length	**Height**	**Type**	**Features**

3. Ziffer = Type		4. Ziffer	
0	closed general purpose	0	end opening(s)
		1	end & full side opening(s)
		2	end & part side opening(s)
		3	end & roof opening
		4	end & roof & side openings
1	closed vented	0	smaller passive vents upper part
		1	bigger passive vents at upper part
		3, 4	passive vents at upper & lower part
		6	mechanical ventilation, located inside
		8	mechanical ventilation, located outside
2	thermal insulated heated named cargo	0	insulated
		1	insulated
		2	heated
		5	named cargo: livestock
		6	named cargo: cars
3	thermal refrigerated & heated	0	refrigerated, expendable refrigerant
		1	mechanically refrigerated
		2	refrigerated and heated
4	thermal refrigerated and/or heated removable equipment	0	refrigerated, expendable refrigerant
		1	mechanically refrigerated
		2	refrigerated and heated
5	open top	0	end opening(s)
		1	& removable top member in end frame
		2	& side opening(s)
		3	& removable top member in end frame
6	platform based	0	no endwalls
		1	complete fixed end walls
		2	fixed free-standing posts
		3	complete folding end walls
		4	folding free-standing posts
		5	with frame and roof
		6	with frame and open top
		7	skeletal, with open top and ends

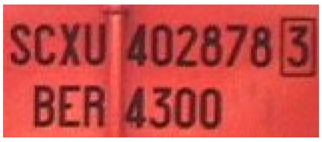


Incorrectly marked platform container

The digit sequence 4364 means: 40' long container 8'6" high with gooseneck tunnel and folding, free-standing posts. It should carry the digit sequence 4363, since the platform container has complete, folding end walls.

7	tank container	0	non-dangerous liquid, 0,45 bar
		1	non-dangerous liquid, 1.5 bar
		2	non-dangerous liquid, 2.65 bar
		3	dangerous liquid, 1.5 bar
		4	dangerous liquid, 2.65 bar
		5	dangerous liquid, 4.0 bar
		6	dangerous liquid, 6.0 bar
		7	dangerous liquid, 10.5 bar
		8	dangerous liquid, 22.0 bar
8	dry bulk	0-9	no specification
9	air/surface	0-9	no specification

Here are some examples of marking in accordance with this older standard:

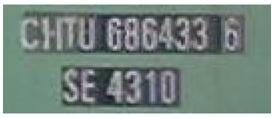


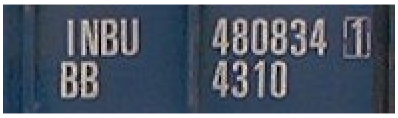
This container is 40' long (4), 8'6" high and has a gooseneck tunnel (3). The type code 00 states that it is a general purpose container which has opening(s) at one or both end(s).

This container is 20' long (2) and 8' 6" high (2). It is a ventilated standard container (1), with narrow, passive vents in the upper part (0).

This container is 40' long (4), 8'6" high and has a gooseneck tunnel (3). It is a ventilated standard container (1), with narrow, passive vents in the upper part (0).

Both of these are 20' containers (2), 8'6" high and constructed as tank containers (7) suitable for transporting hazardous materials to a pressure of 6.0 bar.

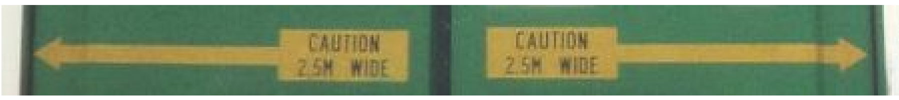




According to the old Annex F "size code designations" annexed to DIN ISO 6346 of August 1985, the two containers are 40' long (number 4) and 8'6" high with a gooseneck tunnel (number 3). According to Annex G "type code designations", both containers are partially ventilated closed containers, which have passive vents in the upper part of the cargo space, the total cross-sectional area of the vents being less than 25 cm² per meter of container length (number combination 10).

However, the coding does not indicate that the green container is 2.50 m wide.

Below:
Warning due to
2.50 m width



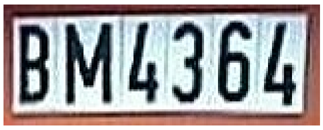
The January 1996 edition of the standard bearing the same number includes another "size code", which has eradicated these inadequacies.

Like the above containers, this container is 40' long, 8½' high and has a gooseneck tunnel (number sequence 43). The type code 51 states that it is an open-top container, with openings at one or both end walls and a removable top member in the end frame.

The number sequence 43 stands for a length of 40' a height of 8'6" plus gooseneck tunnel. In each case the container is a flatrack, but

... the number sequence 63 is the code for a platform with complete folding end walls

... and the number sequence 64 is the code with a platform with folding, free-standing corner posts.



This flatrack allows verification of the coding, identification and marking according to old DIN EN ISO 6346 (1985), showing clearly that it is still valid, since the photo was taken in 2001. The marking beneath the container number reads RCX 4364.

According to the old country code, RCX stands for China (Taiwan). The size code 43 states that it is a 40' container 8'6" high and with a gooseneck tunnel. The number combination 64 states that it is a platform with folding, free-standing corner posts.

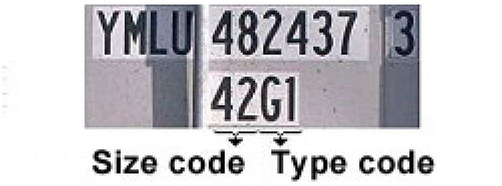
Similar flatracks exist which are 20' long and 8'6" high, of course, but they don't have goosenecks. This is clear from the number sequence 22. The type code 64 is the same as for the previous example: platform with folding, free-standing corner posts.

Both containers have a nominal length of 40', but are higher than 8'6" and each have a gooseneck tunnel (size code number sequence 45). According to type code 10, both containers are partially ventilated closed containers, which have passive vents in the upper part of the cargo space, the total cross-sectional area of the vents being less than 25 cm² per meter of container length.

According to the old 1984 standard:
4 = 40' Container
5 = > 8'6" high with gooseneck tunnel
3 = thermal
2 = refrigerated & heated

These photos show clearly that the container is a 40' long refrigerated container. According to the size code, the container height is > 8'6" - this is correct, as the container is 9½ feet high. The number combination 32, given as the type code, states that the container may be refrigerated or heated.

The following photo shows a variant of horizontal marking with size and type codes:



Size and type codes additionally stated in accordance with current standard

The container is 12,192 mm (40') long, 2,438 mm (8') wide and 2,591 mm (8'6") high. This is a general purpose container without ventilation, but which does have vents in the upper part of the cargo space.

The current standard, used for this marking, is not limited to numbers but also uses letters to make marking more precise. In addition, swap-bodies and the like are also covered by the coding. The superordinate term for both numbers and letters is character. The introductory country code has been discontinued.

The first character of the size code indicates the length of the receptacle:

Character	Container length			Character	Container length		
	mm	ft	in		mm	ft	in
1	2,991	10		D	7,450	24	6
2	6,058	20		E	7,820		
3	9,125	30		F	8,100		
4	12,192	40		G	12,500	41	
5	Spare			H	13,106	43	
6	Spare			K	13,600		
7	Spare			L	13,716	45	
8	Spare			M	14,630	48	
9	Spare			N	14,935	49	
A	7,150			P	16,154		
B	7,315	24		R	Spare		
C	7,430						

In the example, the 4 accordingly stands for a 40' container.

The second character is the code for the height and width of the container.

Container width	Charac-ter	Container height			Character for container width	
		mm	ft	in	> 2438mm und < 2500mm	> 2500mm
2,438/ 8'	0	2,438	8			
2,438/ 8'	2	2,591	8	6	C	L
2,438/ 8'	4	2,743	9		D	M
2,438/ 8'	5	2,895	9	6	E	N
2,438/ 8'	6	> 2,895	> 9	6	F	P
2,438/ 8'	8	1,295	4	3		
2,438/ 8'	9	< 1,219	< 4			

The standard type code allows identification of container type and other characteristics. Since this system is not yet complete, the standard recommends use of the group code if special characteristics of the container type have not yet been fixed or are unknown. The highest unassigned code character should be used as a provisional mark when it is necessary to represent significant characteristics which are not yet included in the Table.

Code	Group code	Type	Type code	Principal characteristics
G	GP	Unventilated general purpose container	G0	Openings at one or both end(s)
			G1	Vents in upper part of cargo space
			G2	Openings at one or both end(s), plus "full" openings at one or both sides
			G3	Openings at one or both end(s), plus "partial" openings at one or both sides
			G4	Spare
			G5	Spare
			G6	Spare
			G7	Spare
			G8	Spare
			G9	Spare

Code	Group code	Type	Type code	Principal characteristics
V	VH	General purpose containers with ventilation	V0	non-mechanical ventilation at the lower and upper parts of the cargo space
			V1	Spare
			V2	mechanical ventilation installed in the container
			V3	Spare
			V4	mechanical ventilation installed outside the container
			V5	Spare
			V6	Spare
			V7	Spare
			V8	Spare
			V9	Spare

Code	Group code	Type	Type code	Principal characteristics
B	BU	Dry bulk containers, non-pressure-resistant	B0	closed
			B1	airtight
			B2	Spare
		Dry bulk containers, pressure-resistant	B3	horizontal discharge, test pressure 150 kPa)[1]
			B4	horizontal discharge, test pressure 265 kPa
			B5	tipping discharge, test pressure 150 kPa
			B6	tipping discharge, test pressure 265 kPa
			B7	Spare
			B8	Spare
			B9	Spare

[1]) 100 kPa = 1 bar = 105 Pa = 105 N/m^2 = 14.5 lbf/in^2 (PSI)

Code	Group code	Type	Type code	Principal characteristics
S	SN	Named cargo containers	S0	Livestock container
			S1	Automobile container
			S2	Living fish container
			S3	Spare
			S4	Spare
			S5	Spare
			S6	Spare
			S7	Spare
			S8	Spare
			S9	Spare

Code	Group code	Type	Type code	Principal characteristics
R	RE	Thermal containers - refrigerated - refrigerated and heated - self powered refrigerated/heated	R0	mechanically refrigerated
	RT		R1	mechanically refrigerated and heated
	RS		R2	mechanically refrigerated
			R3	mechanically refrigerated and heated
			R4	Spare
			R5	Spare
			R6	Spare
			R7	Spare
			R8	Spare
			R9	Spare

Code	Group code	Type	Type code	Principal characteristics
H	HR	Thermal containers - refrigerated and/or heated with removable equipment	H0	refrigerated and/or heated with removable equipment located externally, coefficient of heat transfer K = 0.4 W/(m² · K)
			H1	refrigerated and/or heated with removable equipment located internally
			H2	refrigerated and/or heated with removable equipment located externally, coefficient of heat transfer K = 0.7 W/(m² · K)
			H3	Spare
			H4	Spare
	HI		H5	insulated, coefficient of heat transfer K = 0.4 W/(m² · K)
			H6	insulated, coefficient of heat transfer K = 0.7 W/(m² · K)
			H7	Spare
			H8	Spare
			H9	Spare

Code	Group code	Type	Type code	Principal characteristics
U	UT	Open-top containers	U0	Opening(s) at one or both end(s)
			U1	Opening(s) at one or both end(s) plus removable roof in end frame
			U2	Opening(s) at one or both end(s) plus opening(s) on one or both sides
			U3	Opening(s) at one or both end(s) plus opening(s) on one or both sides plus removable top members
			U4	Opening(s) at one or both end(s) plus opening(s) on one side plus full openings on the other side
			U5	Full, solid side and end walls (no doors)
			U6	Spare
			U7	Spare
			U8	Spare
			U9	Spare

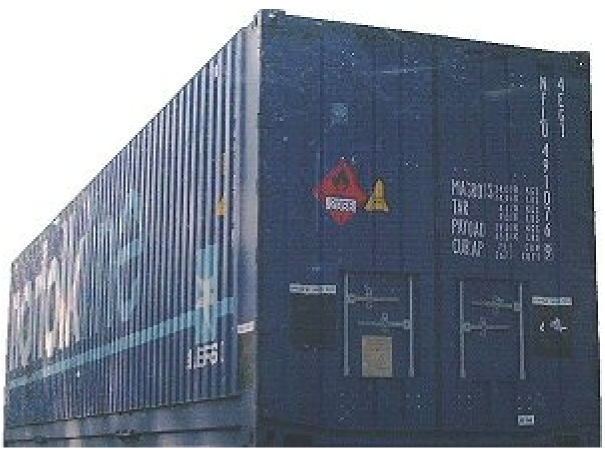
Code	Group code	Type	Type code	Principal characteristics
P	PL	Platform (containers) - platform based con-tainers with incomplete superstructure - fixed - folding - platform based con-tainers with complete superstructure	P0	Platform

	PF		P1	Platform with two complete, fixed end walls
			P2	Platform with fixed posts, either free-standing or with removable top members
	PC		P3	Platform with folding complete end walls
			P4	Platform with folding posts, either free-standing or with removable top members
	PS		P5	Platform, open at the top and ends (skeletal)
			P6	Spare
			P7	Spare
			P8	Spare
			P9	Spare

Code	Group code	Type	Type code	Principal characteristics
T	TN	Tank container for non-dangerous liquids	T0	Minimum pressure 45 kPa [1])
			T1	Minimum pressure 150 kPa
			T2	Minimum pressure 265 kPa
	TD	Tank container for dangerous liquids	T3	Minimum pressure 150 kPa
			T4	Minimum pressure 265 kPa
			T5	Minimum pressure 400 kPa
			T6	Minimum pressure 600 kPa
	TG	Tank container for gases	T7	Minimum pressure 910 kPa
			T8	Minimum pressure 2 200 kPa
			T9	Minimum pressure (yet to be assigned)

[1]) 100 kPa = 1 bar = 105 Pa = 105 N/m^2 = 14.5 lbf/in^2 (PSI)

Code	Group code	Type	Type code	Principal characteristics
A	AS	Air/surface containers	A0	



This Figure shows a variant of vertical container marking, with size and type code (on the left):

The identifying details are more or less clearly visible.

Vertical container marking

Identifying mark plus size and type codes in horizontal arrangement

The container is 12,192 mm or 40' long (number 4 of first character of the size code). Its height is 2,895 mm or 9'6" and its width is greater than 2,438 mm or 8' and is less than or equal to 2,500 mm (letter E or second character of the size code). As regards type, the container is a general purpose container without ventilation, whose main characteristic is that it has vents in the upper part of the cargo space (characters G1 of the type code).

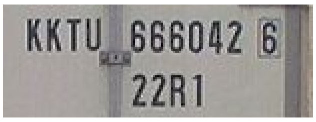
The owner code NFI and product group code U are also known as the alpha prefix. The check digit is often written in a box: 9.

There now follows a number of examples of marking according to DIN EN ISO 6346, January 1996:

According to the two characters 42 of the size code, the container is 12,192 mm or 40' long, 2,591 mm or 8'6" high and 2,438 mm or 8' wide. The type code characters G0 state that the container is a general purpose container without ventilation but with openings at one or both end(s).

According to the two character combinations 22 and 42 of the size code, the container on the left is 6,058 mm or 20' long and the two containers on the right are 12,192 mm or 40' long. All the containers are 2,591 mm or 8'6" high and 2,438 mm or 8' wide. The type code characters G1 state that the container is a general purpose container without ventilation but with vents in the upper part of the cargo space.

According to the two characters 22 of the size code, the container is 6,058 mm or 20' long, 2,591 mm or 8' 6" high and 2,438 mm or 8' wide. The type code characters P3 state that the container is a platform based container with folding complete end walls.



According to the two characters 22 of the size code, the container is 6,058 mm or 20' long, 2,591 mm or 8' 6" high and 2,438 mm or 8' wide. The type code characters R1 state that the container is a thermal container which can be mechanically refrigerated and heated.

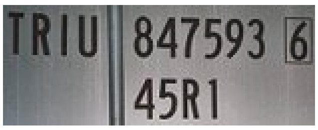
According to the two characters 28 of the size code, the container is 6,058 mm or 20' long, 1,295 mm or 4' 3" high and 2,438 mm or 8' wide. The type code characters P2 state that the container is a platform container with fixed posts, either free-standing (as here) or with removable top members.

According to the two characters 42 of the size code, the container is 12,192 mm or 40' long, 2,591 mm or 8'6" high and 2,438 mm or 8' wide. The type code characters U1 state that the container is an open-top container which may additionally be equipped with opening(s) at one or both end(s) plus removable top door rail in the end frame.

According to the two characters 45 of the size code, the container is 12,192 mm or 40' long, 2,895 mm or 9'6" high and 2,438 mm or 8' wide. The type code characters G1 state that the container is a general purpose container without ventilation but with vents in the upper part of the cargo space.

According to the two characters 45 of the size code, the container is 12,192 mm or 40' long, 2,895 mm or 9'6" high and 2,438 mm or 8' wide. The type code character P indicates that the container is a platform based container with complete end walls. The standard still gives type code P8 as being "spare".

Type code P8 has been used here for a "collapsible flat" (to the right), i.e. the end walls are collapsible for empty carriage.



According to the two characters 45 of the size code, the container is 12,192 mm or 40' long, 2,895 mm or 9'6" high and 2,438 mm or 8' wide. The type code characters R1 state that the container is a thermal container which can be mechanically refrigerated and heated.

According to the character 4 of the size code, the container is 12,192 mm or 40' long. The character C indicates that the container has a height of 2,591 mm or 8' 6" and a width ranging between > 2,438 mm and < 2,500 mm. According to type code G1, the container is a general purpose container without ventilation, which nonetheless has vents in the upper part of the cargo space.

The character 4 stands for the length 12,192 mm or 40'. E states that the container has a height of 2,895 mm or 9' 6" and a width ranging between > 2,438 mm and < 2,500 mm. The type code characters G1 state that the container is a general purpose container without ventilation but with vents in the upper part of the cargo space.

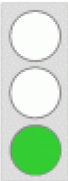
Given the large number of containers available today, it is impossible to tell how long the current codings will suffice and when more characters will need to be introduced.

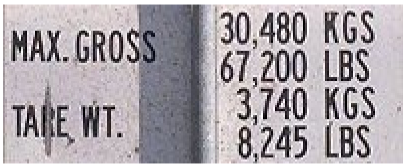
3.5 Operational markings

The operational markings according to DIN EN ISO standard 6346, January 1996, are intended to simplify use of the container by providing additional information and warnings.

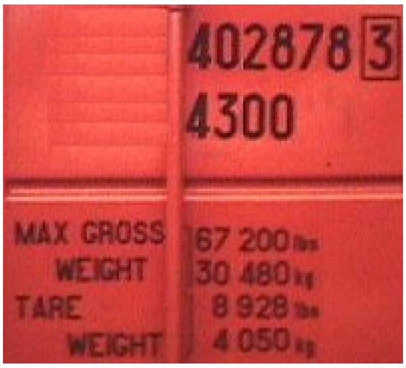
These markings also include both compulsory and optional markings. Examples of compulsory markings are those indicating gross weight and tare weight, which naturally have to agree with those on the CSC Approval Plate.

The standard prescribes the following form and sequence for marking of gross and tare weights:





Standard operational markings: gross and tare weights

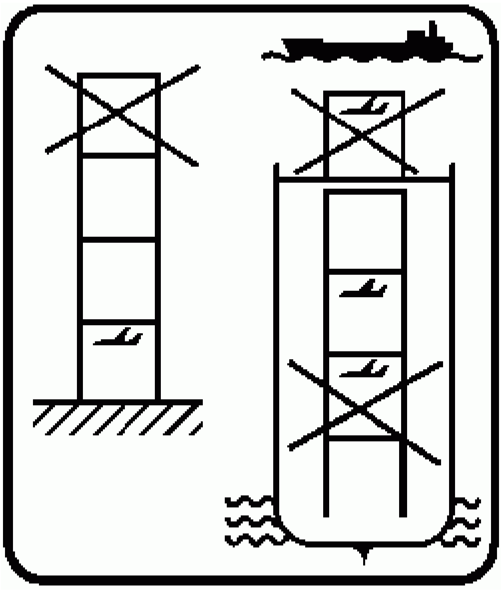


Non-standard operational markings: gross and tare weights

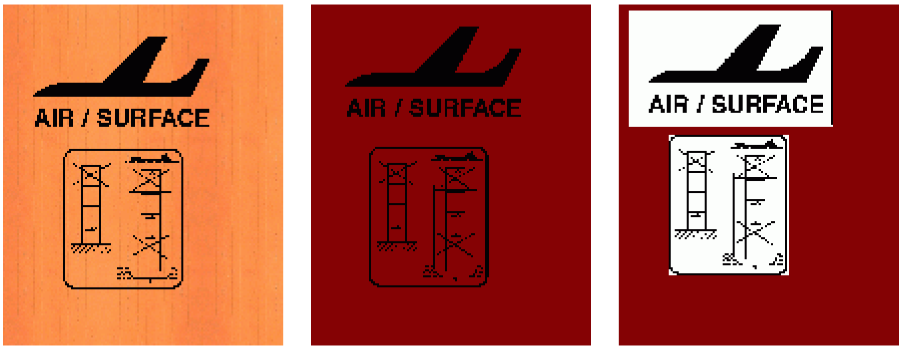
On this container, the minimum compulsory marking requirements are fulfilled as far as the data are concerned, but the sequence is wrong, the English customary values being given first.

It is also compulsory to affix certain warning symbols. These include pictograms for air/surface containers, the danger posed by overhead power cables and height markings for containers which are higher than 2.6 m (8'6").

All air/surface containers should carry the following pictograms:



To indicate that these containers have limited stackability, the symbols should be affixed where possible in the upper left-hand corner of the end and side walls and the roof. The symbol is in black. If the color of the container makes it difficult to see the symbol clearly, it should be applied to a different background of a more suitable color, preferably white.



Distinguishability of labels against different background colors

According to the standard, the symbols should have the following dimensions: aircraft 130 mm (5"), stackability symbols 280 mm (11") high and 260 mm (10") high. The capital letters should be at least 80 mm (3") high.

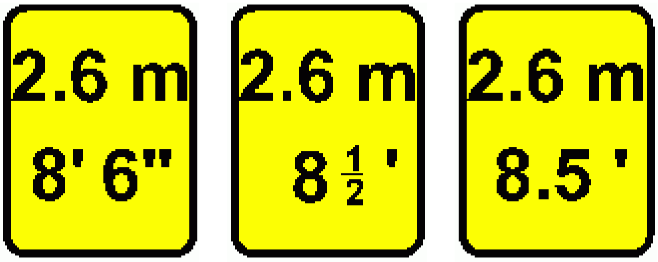
All containers equipped with ladders must be provided with a warning symbol, which indicates the danger posed by overhead power cables.

The height of the lightning in the warning symbol must be at least 175 mm (6.875"). The size of the warning symbol, measured between the outer edges of the black border, must be no less than 230 mm (9"). The symbol must be affixed in the vicinity of the ladder.

Symbol warning against the danger posed by overhead power cables

(2) = Non-standard warning symbol

It is sensible to affix the lightning symbol (2) to the upper part of the ladder (1). It is not necessary, however, to affix signs (3) indicating that the container has a height of 2.6 m or 8'6".

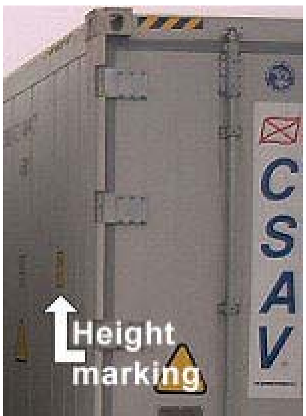


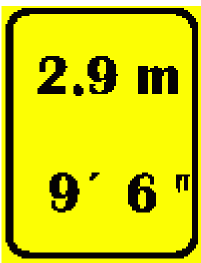
Different ways of writing 2.6 m and the English customary dimension

DIN EN ISO 6346 of January 1996 stipulates that all containers higher than 2.6 m (8'6") must carry the following compulsory markings:

- a height marking on each side
- yellow and black stripes, visible at the top and side, which must be affixed in the upper part of each side and end. These must start at the corner castings and extend at least 300 mm (12").

The height marking must be at least 155 mm high and 115 mm wide (6" x 4.5"). The characters should be as large as possible, so that they are clearly visible. The sign should be affixed at least on each side of the container, in each case in the vicinity of the right-hand edge no more than 1.2 m (4') from the top edge of the container and no more than 0.6 m (2') from the right-hand edge (beneath the identification number).

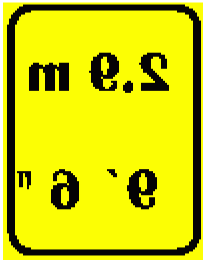




Height marking for containers > 2.6 m high

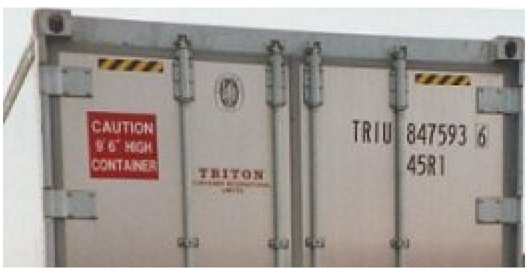
Yellow and black stripes constitute part of the height marking

Optional markings, such as mirror images of the height marking at every suitable point (e.g. end wall), may be affixed.



Mirror image of the height marking

In mirror image:
9'6" HIGH CAUTION



Optional height marking

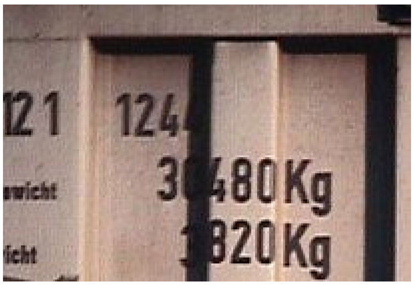
It has always been usual to mark high-cube containers with optional markings of various designs. The upper pair of images show a container marked according to the January 1996 edition of DIN EN ISO 6346, while the lower pair show a container marked according to the August 1985 edition of DIN ISO 6346.

It is always sensible to emphasize the height of individual containers, even if it doesn't always help.

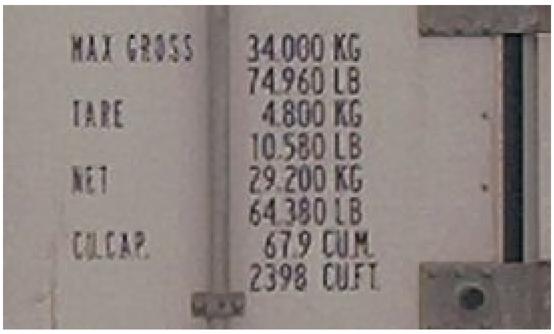
Height markings do have to be observed.

One possible optional operational marking which most operators do affix states maximum payload or net cargo weight, which is the difference between the maximum gross weight and the tare weight of a container. Although this marking is optional, the standard does stipulate that the weight labeled NET be given first in kilograms and then in pounds. In general, the various markings are so arranged that the weight data are followed by container volume data.

Weight and volume markings on 40' containers



Partially hidden or covered weight and volume data

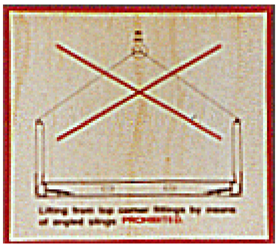


The maximum gross weight may well deviate from the standard values.

M.G.W. = Maximum Gross Weight …. and in Chinese characters too

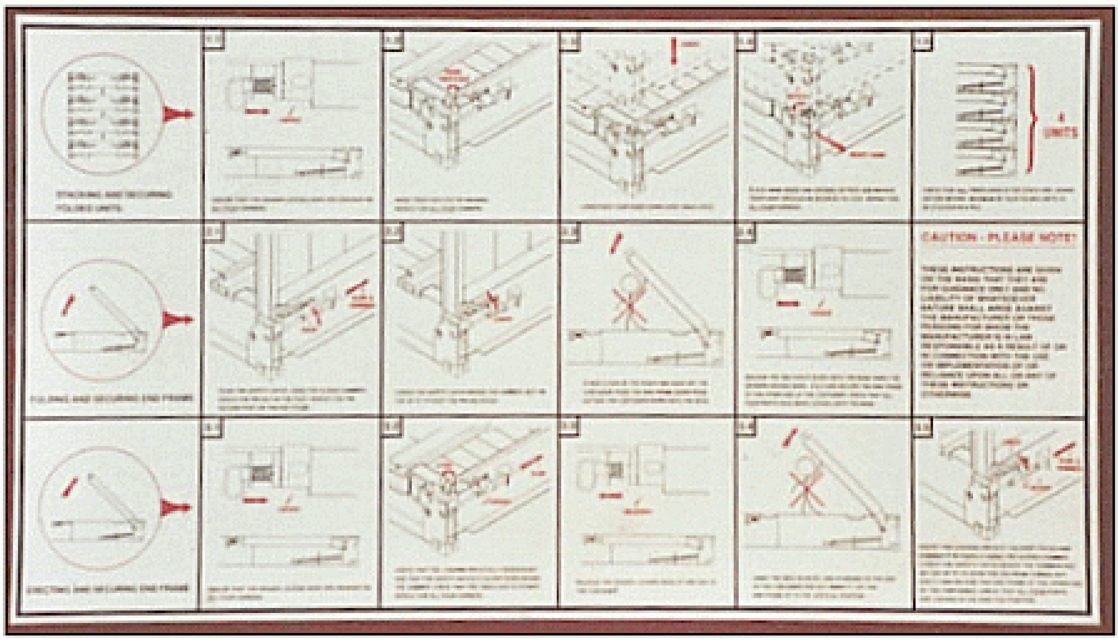
3.6 Other markings

Many containers carry instructions about using particular structural elements, which are intended to serve as warnings.



How not to pick up a load

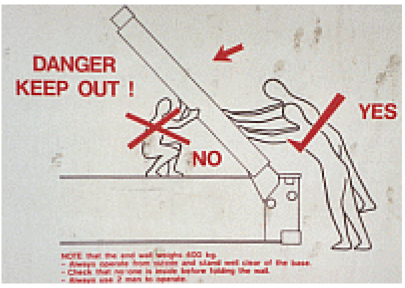
Apart from very few exceptions, containers may only be lifted vertically by the upper corner posts.



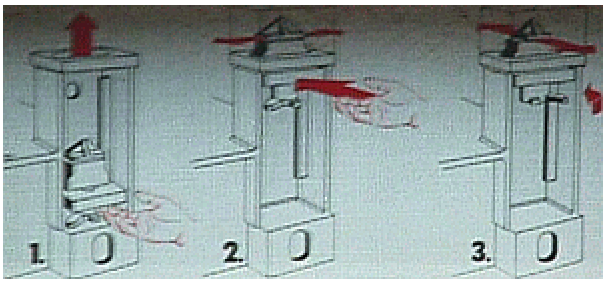
Safety instructions on a collapsible flatrack

It is not necessary to be able to read the instructions in the picture. The point is simply that there are such instructions describing how a collapsible flatrack is to be erected and collapsed and what points have to be observed.

It should go without saying that inexperienced people should not be trusted with such activities. In any case, trained personnel also need to heed such instructions.



Safety instructions on a collapsible flatrack - details

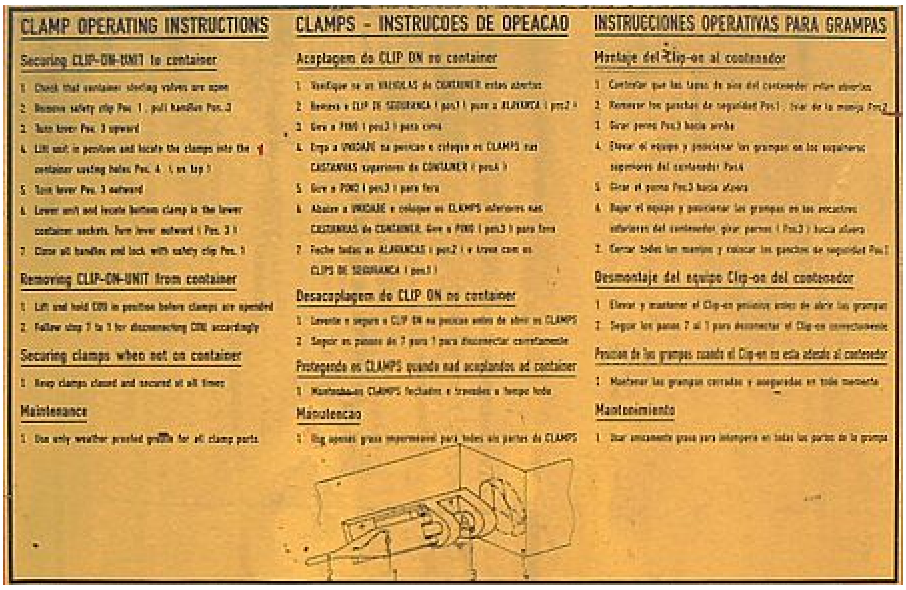


Above and left:
Instructions for using the fitted twist lock

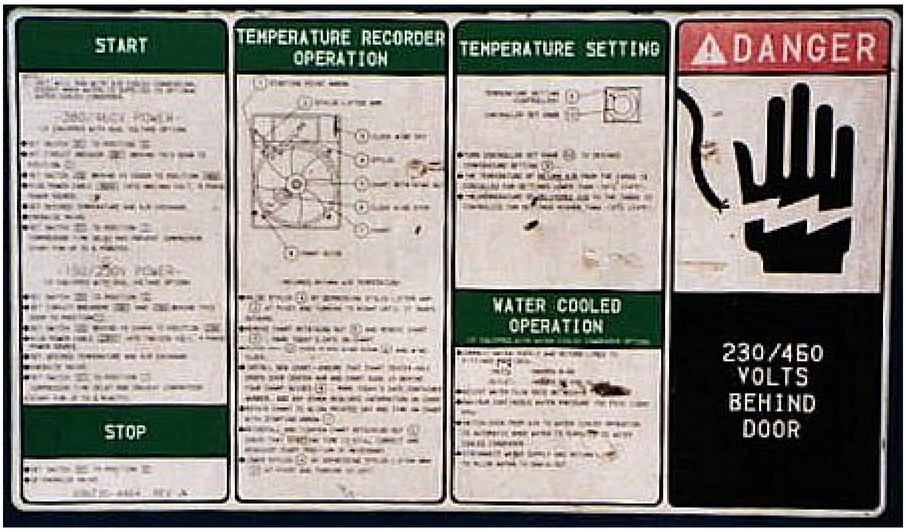
Safety instructions for empty transport

Label pointing out lubrication points

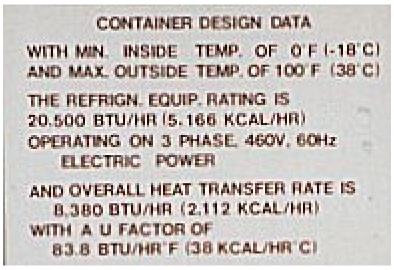
Warning about folding door on a half-height open-top container



Instructions for securing a clip-on unit

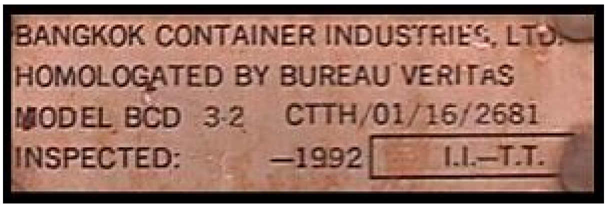


Operating and safety instructions on a thermal container



Above: Information about material used for walls

Left: Technical data on a thermal container



Statement of compliance with structural regulations from Bureau Veritas

Details of owner, manufacturer and treatment of plywood floor in accordance with Australian requirements

Above and left:
Details of owner
and manufacturer

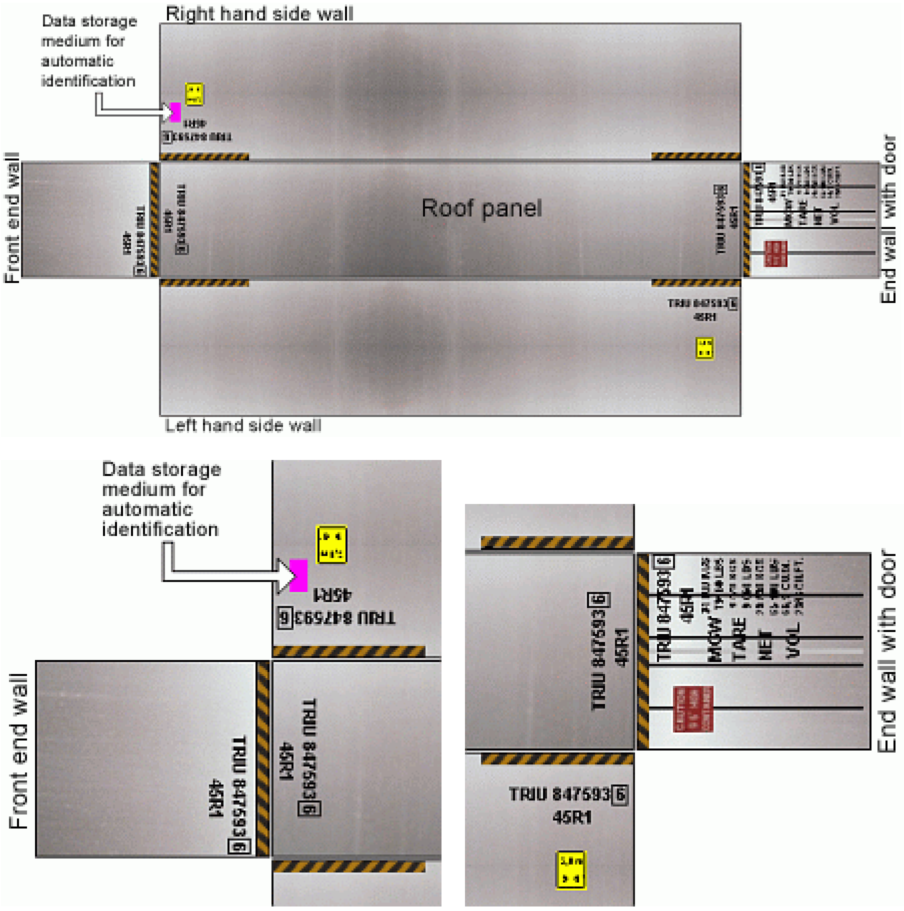
The instructions in the right-hand Figure state: CAUTION: Left-hand door must remain locked closed at all times if loaded boxes are stacked on top!

Right and left:
Safety instructions

Above: this red line indicates the "max. load height" in order to ensure air circulation during cooling operation.

Warnings about
extra-large width

3.7 Arrangement of obligatory and optional markings



Top and selective enlargements below:
Arrangement of obligatory and optional markings

The relevant standard allows for the areas of yellow and black stripes next to the corner castings to be reduced to a length of 300 mm (12").

It will be noted that the standard does not conform with the regulations in the German road traffic code and those of other countries, since in the standard the diagonal black and yellow stripes always run in the same direction.

Standard arrangement of black and yellow stripes

More sensible, mirror-image arrangement of black and yellow stripes

Marking error - the yellow and black stripes are absent at c

More sensible affixing of yellow and black stripes, which are present at c. Stripe b is mirrored relative to stripe a.

Non-standard but sensible Standard of black and yellow stripes

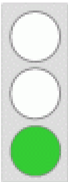
Red and white plates: correct

Red and white plates: incorrect

Correctly affixed red and white warning plates

Only this symmetrical arrangement of the warning plates, as provided for in the regulations, makes any sense.

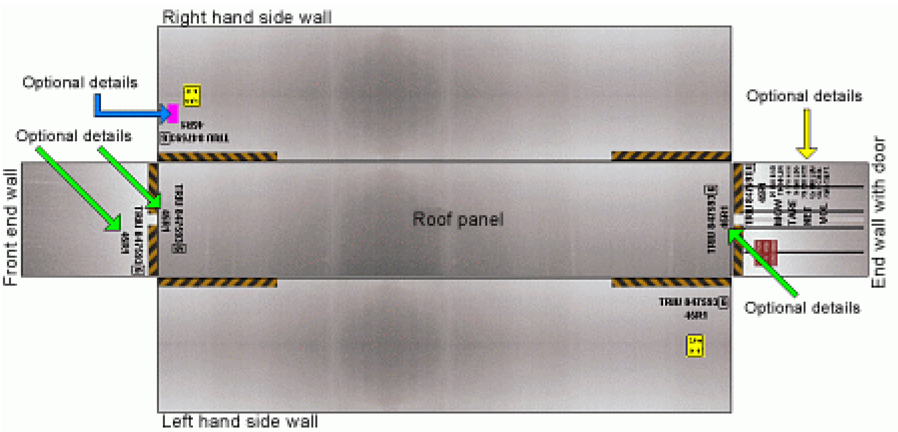
This vehicle with correctly affixed warning is a particularly clear illustration.

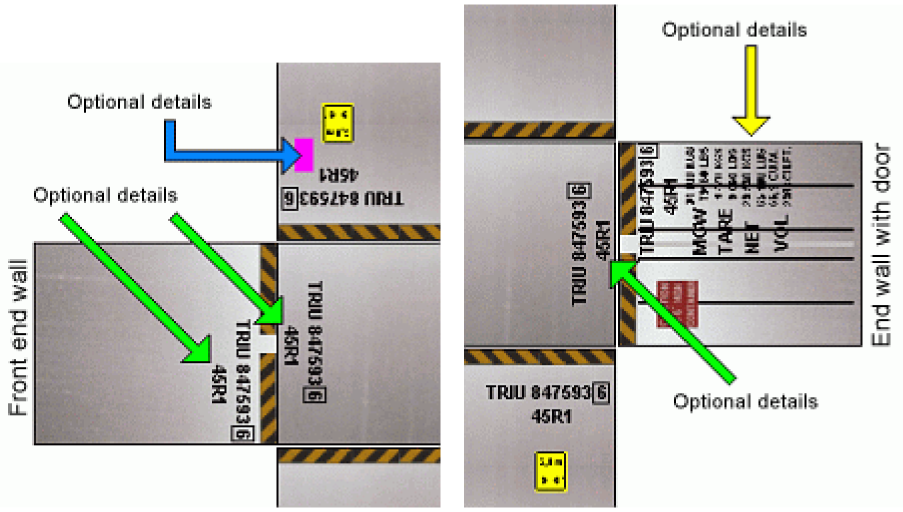


Correctly painted red and white warning

Desirable arrangement of black and yellow warning markings

It would be a good idea if this were taken into consideration when the standards are revised.





Top and selective enlargements below:
Optional details are indicated by colored arrows.

The standards allow for optional affixing of size and type codes to the roof and front end wall (green arrows). The same applies to affixing a data medium for automatic identification (blue arrow) and to marking of the net cargo weight (yellow arrow).

3.8 Marking of containers carrying dangerous cargoes

The CTU packing guidelines state in Section 4.4.1 in relation to placarding of containers carrying dangerous cargoes:

> *4.4.1.1 Placards (enlarged labels) (minimum size 250 mm x 250 mm) and, if applicable for maritime transport, "MARINE POLLUTANT" marks (minimum size of a side 250 mm) and other signs should be affixed to the exterior surfaces of a CTU or unit load or overpack to provide a warning that the contents of the unit are dangerous cargoes and present risks, unless the labels, marks or signs affixed to the packages are clearly visible from the exterior of the unit. This type of marking can be omitted on unit loads and overpacks if the hazard labels, markings or warning symbols are clearly visible from the outside.*

Correct marking on a container side

The container is loaded with Class 4.1 flammable solids.

Correct marking on a container side

The container is loaded with Class 3 goods, i.e. flammable liquids, which are also marine pollutants.

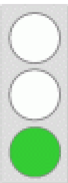
The CTU packing guidelines give additional instructions for affixing placards, these being explained in more detail in the CTU packing guidelines Point 4.4.1.2: This paragraph reads:

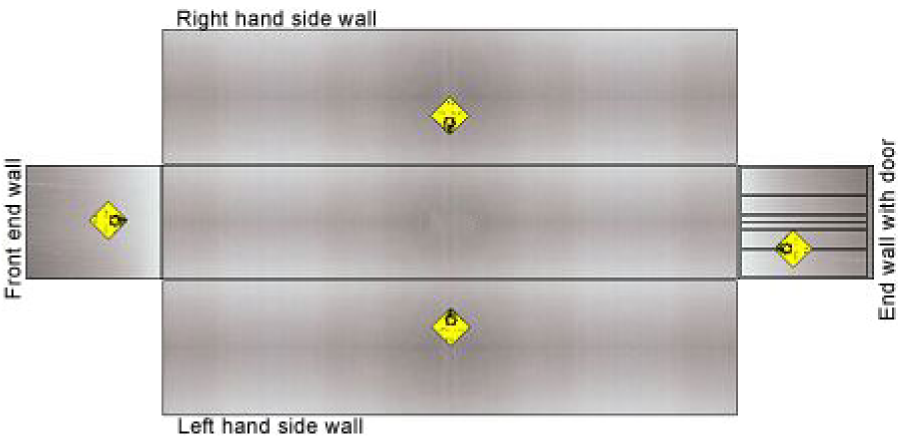
> *(4.4.1.1 contd.) If possible, the placards, hazard labels, markings or warning symbols on the outsides of the CTU should not be obscured when the CTU is opened.*

Non-regulation affixing of a placard

4.4.1.2 CTUs containing dangerous cargoes or residues of dangerous cargoes should clearly display placards and, if applicable for maritime transport, "MARINE POLLUTANT" marks or other signs as follows:

1. *a container, one on each side and, in the case of carriage by ocean-going vessel, also one on each of the ends of the unit;*
2. *a railway wagon [railroad car], at least one on each side;*
3. *any other CTU, at least one on both sides and on the back of the CTU and, in the case of a semitrailer, also one on the front of the CTU.*





Correct marking of a container for maritime transport according to the CTU packing guidelines

It has been proposed to mark the roof with a corresponding placard, in order to warn lifting gear or ground conveyor operators when picking up such a container. However, the regulations do not as yet contain any such obligation.

Point 4.4.1.2 of the CTU packing guidelines continues:

Placards on the sides of a CTU should be affixed in such a position that they are not obscured when the unit doors are opened.

The "if possible...not be obscured" of 4.4.1.1 has become an obligation: "should be affixed".

Point 4.4.1.3 deals with dangerous cargoes which present several risks:

Whenever dangerous cargoes present several risks, subsidiary risk placards should be displayed in addition to primary risk placards.

The regulations covering this area were amended in 2002. According to the old regulations, the primary risk placards had to carry the correct class number, while the subsidiary risk placard was not supposed to carry any class numbers.

Three old variants of primary and subsidiary risk placards

The way this requirement was fulfilled was open to choice and it was of no significance whether the class numbers were obscured by being painted or stuck over or cut off.

According to the regulations in force since 2002, both primary and subsidiary risk placards must carry the class numbers.

New regulations:
Primary and subsidiary risk placards bear class number.

Point 4.4.1.3 of the CTU packing guidelines continues:

... CTUs containing cargoes of more than one class, however, need not bear a subsidiary risk placard if the hazard represented is already indicated by the primary risk placard.

Dangerous cargo container carrying dangerous goods of various classes

For dangerous cargo containers carrying dangerous goods of only one class, the regulations in point 4.4.1.6 of the CTU packing guidelines apply:

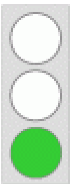
> *Consignments of packaged dangerous cargoes of a single commodity, other than cargoes of class 1, which constitute a full load for the CTU should have the UN Number for the commodity displayed in black digits not less than 65 mm high either against a white background in the lower half of the class placard or on an orange rectangular panel not less than 120 mm high and 300 mm wide, with a 10 mm black border, to be placed immediately adjacent to the placard (see Annex 2). In those cases the UN Number should be displayed immediately adjacent to the Proper Shipping Name.*

According to the IMDG Code, the regulation applies from a mass of 4,000 kg.

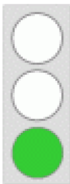
The container contains only one dangerous cargo, i.e. Class 5.1 oxidizing substances (agents), which increase the risk and intensity of fire, and are also corrosive. The (yellow) primary risk placard correctly carries the number 5.1, but the subsidiary risk placard does not carry the number 8 (also correct according to the old regulations), which has been obscured. According to the currently applicable regulations, this placard would also have to carry the class number 8.

Primary and subsidiary risk placards plus UN Number.

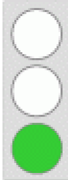
The placards have been incorrectly positioned. They are obscured when the door is opened.

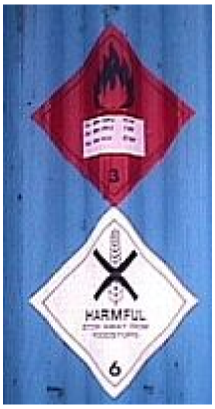


Correct: 4,000 kg consignment with hazardous materials, therefore UN number stated



Correct: < 4,000 kg consignment with hazardous materials, therefore UN number not stated





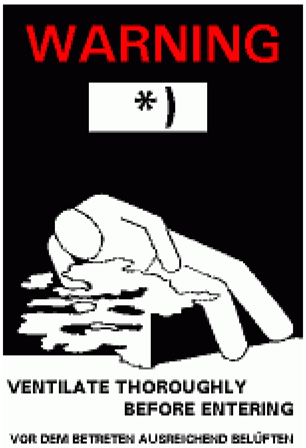
Incorrect: < 4,000 kg consignment with hazardous materials, no UN number stated

Correct: two classes, therefore no UN Number (the placard is obsolete and class 6.1 has since been replaced with a death's head and the word "Toxic").

Point 4.4.1.9 of the CTU states the following:

> *When solid carbon dioxide (CO_2 - dry ice) or other expendable refrigerant is used for cooling purposes, a warning sign should be affixed to the outside of the doors so that it is clearly visible to any person operating the doors. The sign should warn of the possibility of an asphyxiating atmosphere. ...*

The name of the gas used as refrigerant should be inserted beneath the word WARNING.



Warning sign for CTUs in which dry ice or other expendable refrigerants are used for refrigeration purposes

The IMDG Code recommends the following wording for the "Container Packing Certificate":

> *When solid carbon dioxide (CO_2 - dry ice) is used for cooling purposes, the container/vehicle is externally marked or labelled in a conspicuous place, such as, at the door end, with the words:*
> *"DANGEROUS CO_2 (DRY ICE) INSIDE.*
> *VENTILATE THOROUGHLY BEFORE ENTERING."*

The CTU packing guidelines contain a reminder that cargoes under fumigation may require special precautions:

> *4.4.1.10 As CTUs offered for shipment under fumigation may require special precautions, they should only be accepted with the agreement of the carrier and they should be identified to him prior to loading. CTUs under fumigation are now included in class 9 of the IMDG Code.*

The following is stated about the labeling of such CTUs:

> *4.4.1.11 When a closed CTU or its contents has been fumigated and is to be shipped under fumigation, a warning sign should be affixed to the outside of the doors so that it is clearly visible to any person operating the door. An example of such a warning sign is given in Annex 2. The sign should state the fumigant, the method of fumigation employed and the date and time when it took place. The sign should only be removed when the unit has been ventilated after fumigation, to ensure that no harmful concentration of gas remains.*

The intention of this Section was merely to provide some tips for marking dangerous cargo containers. In a real packing situation, obviously, the other regulations in the CTU packing guidelines should be consulted, especially the valid dangerous cargo regulations.

Picture of the warning sign "FUMIGATION WARNING"

4 Loading and load securing

Preface

Load securing cannot be defined as simply the physical securing of a consignment using friction and tight-fit methods. Instead, it should be taken to be the "Safety of loads and protection against potential damage by loads" and should cover:

- protection of the goods against all forms of damage and/or
- protection of the environment against potentially damaging effects of the cargo.

An all-inclusive approach such as this may encourage greater interdisciplinary thinking and consideration of the problems of load securing in context rather than as an isolated issue. Load securing, in its broadest sense, is dependent on a number of factors:

- the characteristics of the goods that are being transported
- the construction and/or manufacturing features
- the types packing and packaging used
- the cargo transport units chosen for transportation
- the aids and devices used during packing
- the packing methods
- the securing methods
- the materials used to secure the load
- the finish of the materials used to secure the load
- the transport methods and routes used etc.

As always, the people responsible for the overall process play a critical role. Only when these people have been trained properly and have the right experience is it possible to minimize damage. Only the use of the correct and appropriate forms of load securing is able to prevent damage being caused to the goods that are being transported as well as to equipment, public property and the environment.

Note regarding legal stipulations

Packing of containers and cargo securing in or on containers must be carried out in accordance with the "CTU packing guidelines" published by the "International Maritime Organization". The exact title of the document is "IMO/ILO/UN ECE Guidelines for Packing of Cargo Transport Units (CTUs)".

The "Scope" section of the CTU guidelines contains information about situations where these guidelines are not applicable. This states:

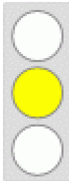
> *They do <u>not</u> cover the filling or emptying of tank containers, portable tanks, or road tank vehicles, or the transport of any bulky cargo in bulk packagings.*

CTU guidelines do not apply to tanks and bulk cargo

The "Definitions" section defines a number of terms:
bulk cargoes *means cargoes which are intended to be transported without any intermediate form of containment in bulk packagings or portable tanks.*
cargo *means any goods, wares, merchandise and articles of any kind which are intended to be transported.*
dangerous cargoes *means packaged, dangerous, hazardous or harmful substances, materials or articles, including environmentally hazardous substances (marine pollutants) and wastes, covered by the International Maritime Dangerous Goods (IMDG) Code. The term "dangerous cargoes" includes any empty uncleaned packagings.*

> ***overpack*** *means an enclosure used by a single shipper (defined in section 8 of the German "Carriage of Dangerous Goods by Sea Ordinance", GGVSee, as the "producer or shipper") to contain one or more packages and to form one unit for convenience of handling and stowage during transport.*
>
> *Examples of overpacks are a number of packages either:*
>
> 1. *placed or stacked on to a load board such as a pallet and secured by strapping, shrink-wrapping, stretch-wrapping or other suitable means; or*
> 2. *placed in a protective outer packaging such as a case or crate;*
>
> ***packaging(s)*** *means receptacles and any other components or materials necessary for the receptacle to perform its containment function.*
> ***packages*** *means the complete product of the packing operation, consisting of the packaging and its contents as prepared for transport.*

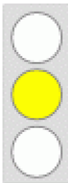





Faulty packaging will affect the entire duration of the transport

> ***unit load*** *means a number of packages that are:*
>
> 1. *placed or stacked on and secured by strapping, shrink-wrapping or other suitable means to a load board such as a pallet;*
> 2. *placed in a protective outer enclosure such as a pallet box;*
> 3. *permanently secured together in a sling.*






Failure to implement unitization correctly makes packing and securing more difficult

In the case of hazardous materials, the unitization shown on the left represents a failure to comply with the General Provisions of the IMDG code.

Unlike conventional methods of loading, closed containers offer better protection against robbery, theft and climate conditions. This is also a form of load securing or, to put it another way, protection of the load.


Loading containers in the rain

For all moisture-sensitive cargoes, namely the vast majority of all general cargo, measures must be taken to ensure that the goods to be loaded are not stored in the open whether it be for long or short term storage, and that they are only packed in roofed areas.

The basic requirements for preventing damage and thus protecting the load are:

1. container-suitable construction of loads, goods and/or packaging, including container-suitable palletization and unitization, as well as
2. the appropriate packing of the load into the container, and if this is not sufficient,
3. supplementing the packing measures by the use of suitable load securing mechanisms.

If these three rules are observed, the container is able to carry out the protective function it was designed for. Failure to comply with these basic rules, however, means that the containers are endangered by their own cargo.

Damaged end wall, caused by a badly packed and unsecured cargo

Palletization in a form not suitable for containers

Palletization in a form suitable for containers

The only criticism that can be leveled at the pallets is the way the straps have been placed and the fact that this has been carried out using steel strapping. The use of plastic strapping and edge protectors would have been preferable. Top marks, however, must be awarded for the fact that the second layer has been placed on top of interlayer dunnage.

This section of the Container Handbook has been designed to show the basics required in order to transport cargo without damaging it or anyone/anything else.

The "Scope" section of the CTU packing guidelines states:

> *These Guidelines are not intended to conflict with, or replace or supersede, any existing regulations or recommendations which may concern the carriage of cargo in CTUs.*

This is intended to stress the fact that other regulations will still continue to be valid. For example, the German railroad regulations in which § 1 makes the following statement about the state of the cargo:

> *The cargo must be in a state that does not permit it to present a danger to the safety of the railroad.*

This paragraph affects, in the first instance, the manufacturers, shippers and packers of goods. Other areas of law also have similar regulations - including insurance law. Both the nature and the state of the packaged load and its packaging must meet all requirements for correct transportation. As we have already seen, and we will continue to see, this is very often not the case.

Load securing considerations are an issue as early as the design of products. The manufacturer intends selling their products. To do this, the goods are going to have to travel some distance - in particular goods designed for export. Since the manufacturer has a vested interest in getting their products to their customers in a undamaged state, it makes sense for the producer to enable or facilitate correct securing of the load by incorporating appropriate lashing points. Strictly speaking, the German Law on the Safety of Equipment, for instance, requires the manufacturer to do so.

Since once a load is passed on to the carriers, packing companies, cargo handlers, transport companies etc. the load is no longer in the power of disposal of the shipper, these companies are thus responsible for checking to ensure that the consignment is in a condition suitable for transportation. If faults are detected, measures must be taken to ensure that the goods are made suitable for transport (again).

In the case of hazardous goods, damaged packages must not be loaded under any circumstances. Instructions to the contrary should not be observed.

4.1 Packaging and marking

4.1.1 Packaging receptacles and packaging aids

The influence of packaging receptacles and packaging aids on load securing

Choosing the right type of receptacle and packaging aids has a direct influence on the security of a load, the prevention of damage and the costs of storing, handling and transportation. The main tasks of transport packaging are:

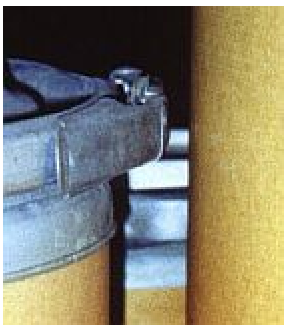
- to protect the cargo from loss, damage or depreciation,
- to protect people, the environment and the transportation vehicle from potential damage caused by the cargo, and also
- to enable high levels of mechanization and rationalization of storage, handling and transportation processes.

These tasks can only be achieved by careful selection of packaging methods, packaging receptacles and aids as well as correct packing.

Modifications are relatively easy to implement for cartons, crates and cases. However, fiber, plastic and steel sheet packaging can only be modified gradually since many filling plants and packaging lines are designed specifically for use with special receptacles. Thus, solutions must be found that take account of the needs of all concerned. This can only be achieved in conjunction with manufacturers, industrial associations and standardization committees. This process also requires considerable investment.

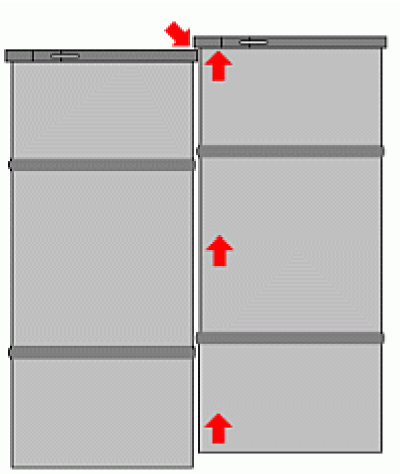
The design of fiber drums, barrels, canisters, pails, corrugated barrels, quick lever-closure drums etc. must be revisited and modified in the long-term, both with regard to the fundamental design and the dimensions of the receptacles.

The risk of damage during transport is disproportionately large for some of the packaging receptacles commonly in use. Furthermore, transport using some of the existing packaging receptacles requires considerable outlay in terms of materials and personnel if the goods packed in these containers are to reach their destination without damage.



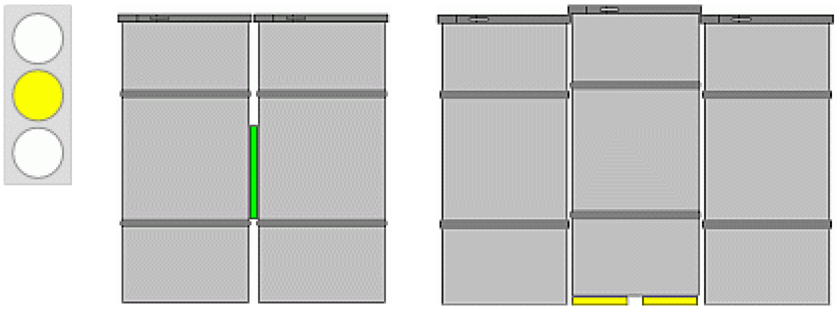
Risk of damage when using commonly available packaging receptacles

The closures on fiber drums, the handles on buckets, pails, canisters, and other similar containers can cause to damage to cargo stored on top of or next to them as a result of high point loading. Professional loading requires the use of additional dunnage, and increases the amount of stowage space lost during packing as well as increasing personnel costs.

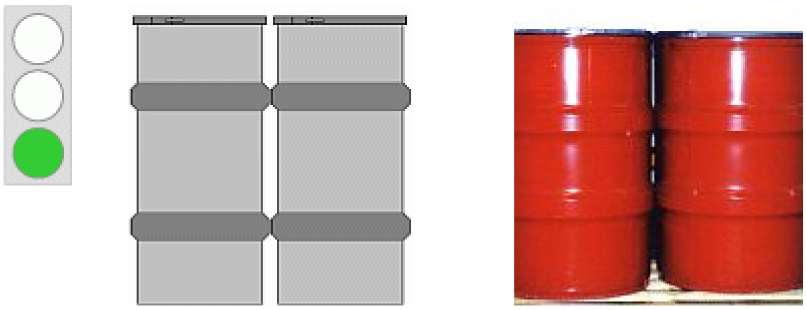


Disadvantages of commonly available drums/quick lever-closure drums

As a result of loads caused during transportation, drums of this type ride up over the corrugations of neighboring drums. This encourages the formation of transport gaps and the damage associated with these. If the levers of quick lever-closure drums extend beyond the edge of the drum, these may snag. The consequences of this include unintentional opening of the drums and/or damage to the drums.



Additional measures to avoid design-related gaps



Avoiding the formation of gaps by using a different drum design

Transport damage caused by gaps formed as a result of the design of the receptacles can only be prevented by employing further materials which leads to additional costs for materials and personnel, or by selecting a different type of drum with wider corrugations and recessed closures. It is obvious that, in the long-term, the selection of a better drum is the more cost-effective solution.

Careless packing is one of the main causes of accidents and damage. Fundamental errors are often made as early as design and production of the goods. This is because storage, handling and transport are rarely taken into consideration at this stage. The same applies to the production and use of various packaging receptacles and packaging aids: These simply do not meet the requirements.

In the majority of cases, however, it is the "packer" who makes the mistakes responsible for damage suffered during transportation. A package is only appropriate for carriage when it is able to withstand all the manipulation to be expected during storage, cargo handling and transportation, also in terms of keeping the environment protected from the goods. Not all packaging faults will cause damage, but the risk to the contents is increased considerably.

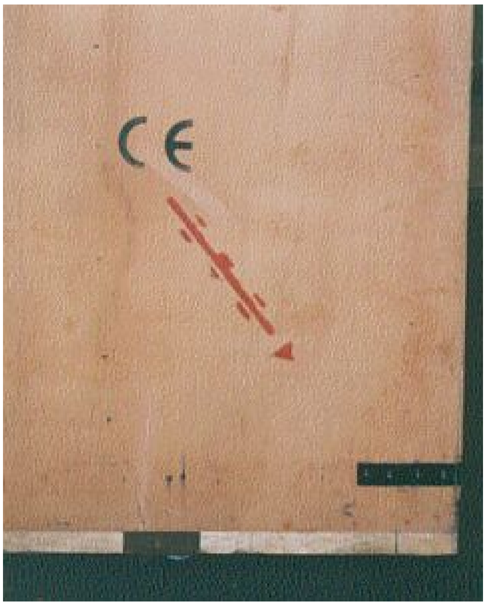
Machine component intended for packing into a container

Because the machine component itself has not been designed to be transported by forklift truck, it has been placed on a pallet (and not secured) for transportation within the company. Simply maneuvering the component into a container is already fraught with a number of difficulties. In order to be able to secure it correctly, considerable outlay in terms of materials and staff hours will be required. If the packaging is designed to act as protection against climatic conditions or corrosion, then the damage to the plastic film that is likely to be caused by necessary securing measures is likely to have negative consequences for the cargo.

What is required is a skid which can be transported using forklift, similar to the floor of a case, and to which the machine component can be bolted. Securing would then be easy. The skid plus machine component could be secured in place in the container using vertical bracing.

Lack of securing in the container as a result of the method of packing

The packing staff often give up when attempting to properly secure objects that are not suitably packaged. The load is simply placed in the container and left to its own devices.



Packaging which is unsuitable for handling

This case does not have any lower skids. In order to be able to comply with the sling here hoisting instructions given by the symbol on the case, or for transportation using a forklift, the forklift operator must force the forks under the case to lift it.

Packaging that is not suitable for storage

The lower skids of this package are completely missing at the rear, and are breaking away at the front. Thus the package is no longer suitable for transportation.

In practice, people fail to assign as much importance to the issue of the suitability of packaging for transportation as they should. The issue affects all types of transportation and is thus not specific to maritime transport alone. It is, however, of particular importance when loading containers for maritime transportation.

The following basic principles may be used to assess the suitability of a load for transportation:

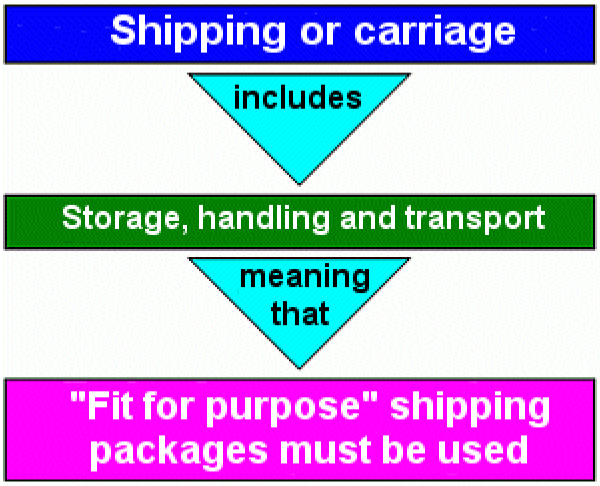
- Loads must be in a state which does not, in any way, affect safety during transport.

- A load is secured appropriately for carriage if, when loaded and handled in the proper manner, it is unable to cause damage to persons, to handling or transportation equipment or to other cargo.

The term "safe for carriage" must be defined in such a way that it is clear to all persons involved in the process. The average lay person can assume that manufacturers of goods and the people and companies entrusted with their transportation are specialists in their field. If the terms shipping and carriage are used, they also cover the storage, handling and transportation of the goods as well as all associated preparation and final work.

It must also be assumed that specialists are aware of the different demands made of small, large, display and sales packaging and are able to differentiate between these demands and the demands made of combination and transportation packaging and load units.

Transportation packaging must be constructed in such a way that it is suitable for carriage in order to ensure that it meets all the demands of handling, storage and transportation. This applies to all aspects: protection of the goods, protection of the environment from the goods, or issues relating to handling, packing, stowage, securing etc.



Unfortunately in some areas, concepts such as ordinary commercial packaging, overseas packaging and seaworthy packaging are still often used. Concepts such as packaging suitable for transport or fit-for-purpose packaging are preferable, since such concepts are used in transport insurance law.

The manufacturers and shippers of goods must, at the very least, inform themselves of the following issues and construct/select suitable packaging formats accordingly.

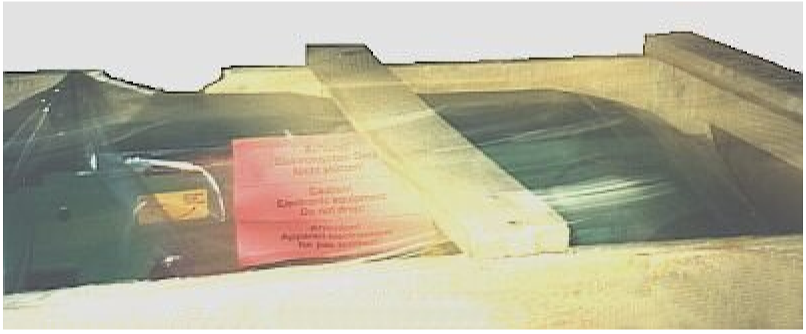
All measures for protecting the goods from damage must focus on the loads experienced during storage, handling and transportation. Goods should always be packed safely if they require protection from complete, or partial loss or from damage, or if the goods themselves represent a risk to the environment. If these basic principles are generally adhered to and the relevant ISO , EN or DIN standards and other technical regulations are also observed, the best conditions for damage-free transportation can be achieved.

In the area of hazardous goods, legislation has generally taken account of the above factors in the form of special packaging regulations. But what is the use of introducing packaging regulations for hazardous goods when they can (and must) be packed into a container with other goods which are less suitably packaged.

Not all packaging faults will cause damage. However, the risk is increased considerably. Poor packaging has an additional psychological effect: Bad packaging promotes carelessness and incorrect handling among handling staff.

An example of bad packaging

It will be difficult to stow other items on top of this crate since part of the contents extend above the top of the wooden crate.



Incorrectly constructed wooden crate

Packing a CTU with packages of this type causes additional expense since so much interlayer dunnage must be employed in order to stack other objects on top of the crate while ensuring that the contents of the wooden crate do not suffer damage.

4.1.2 Unitization and palletization

4.1.2.1 Unitization and palletization, Part 1

The influence of faulty unitization and palletization on load securing

Carelessness and poorly trained personnel are the main reasons for damage caused as a result of faulty palletization and unitization. The following applies: Once again, gaps are the main cause of all mechanical transport damage!

This carton really is in an exposed location. Would anyone actually load this pallet into a mixed consignment container? It is more likely that the steel straps will be cut away and the carton loaded as an individual item.

Palletization which actually increases freight costs

The combination of packaging receptacles, pallet and stretch wrap does not automatically result in a so-called "palletized load", as the example above shows. Only if the handling of pallets can be rationalized using ground conveyors can we really speak of palletized goods. These are handled by a number of companies at a cheaper rate.

Errors that occur frequently are demonstrated by these photographs:

Goods that are not safe for carriage

The quick lever-closure drums shown here are basically not suitable for transportation, since the lids are able to push each other open. This applies to both conventional methods of stowage and to palletization. If this does not happen when the goods are wrapped, as in this case, then it will occur at the very latest when the load is jolted during transport.

Pallets do not usually have diagonal bars which means that are very susceptible to asymmetric forces. In particular when used in containers, pallets can only really be used sensibly when they can be packed flush and have level sides and surfaces. Gaps make it more difficult to pack and secure the load. Shrink and stretch wrap must firmly bond the goods to the pallets. This bond should be able to withstand the normal loads caused by handling. That is not the case here.

When loads arrive at a container packing station in such a pitiful state, the drums should be packed individually. It is obvious that drums or pails designed for use in containers can save on costs.

This picture demonstrates the potential danger that may arise when badly packed pallets are not rigorously unpacked, and instead an attempt is made to load them despite their obvious deficiencies:

An accident waiting to happen due to badly loaded pallets

Despite the fact that this is not permitted, a loader can be seen climbing onto the pallet lifted by the forklift truck in an attempt to stabilize the load. This attempt fails and the drums fall to the ground.

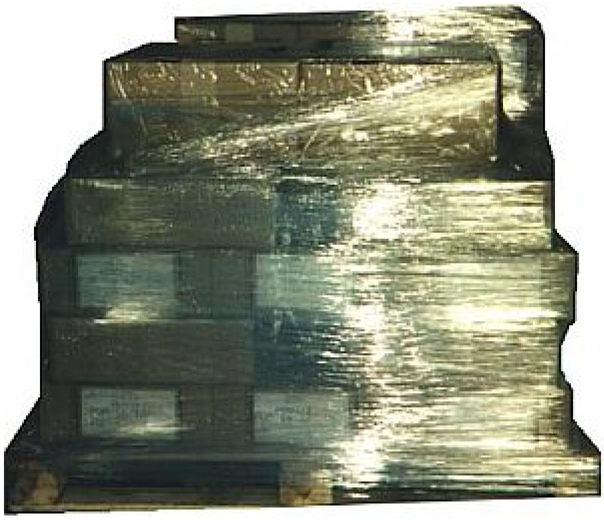
The package illustrated appears, at first glance, to be a perfectly good shrink-wrapped pallet containing boxed goods. The wider dimensions of the load toward the top, i.e. the fact that they extend beyond the bounds of the pallet, may mean that the goods are forced into a gap that is too small for them because they no longer have dimensions suitable for the means of transport. The cartons stacked on top restrict the options for packing other goods on top of this package. In the real world, many packers would slice open the shrink wrap and load these two cartons separately. This subsequently increases the probability of incorrect delivery. A possible reason for this type of unacceptable palletization is that producers tend to apply their pricing/discounting system to round numbers like, for example, 50 or 100 instead of matching it to the capacity of loading aids, transport aids or means of transport.

Two cartons too many!

The most frequently seen error is pallets that are not packed flush.

Incorrectly packed pallets containing boxed goods

Whether the goods are too small for their pallet, extend beyond the bounds of the pallet or are placed diagonally on the pallet, all these instances encourage careless loading into vehicles and containers, make load securing more difficult and can ultimately lead to the load being damaged.

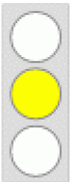


Faulty palletization

Bad palletization is not restricted just to boxed goods. When loading containers with hazardous goods you will often see badly shrink-wrapped or badly strapped pallets.

Load unit that is not suitable for transportation

These load units cannot be stacked. Under the slightest acceleration, the badly wrapped film will not be able to hold the plastic canisters and tin drums in place on the pallet.



These load units are generally well packed, the surfaces are level and they can be stacked. Unfortunately, however, the sides are not perfectly flush with the pallet base. There are still gaps that should be filled.

Deficiencies when forming load units

Note: Ignore palletization …

... at your peril!

Goods that are palletized this badly cannot be stowed safely and without gaps, as the regulations require, without additional outlay in terms of work and materials.

Upper and lower images:
Load units that contravene the regulations

Upper and lower images:
Unacceptable packing of pallets with drums

In road and rail transportation, actions that contravene the general guidelines on palletization can be compensated for by additional outlay on stowage and securing. In maritime transportation and when dealing with hazardous goods, packages of this nature are clearly in breach of the law. The general provisions of the German GGVSee, a German translation of the IMDG code state that the unitization and labeling of items and unit loads to be transported must be carried out in accordance with the regulations. In section 10.18 of the IMDG code, unit loads are defined as a number of packages that are

1. *placed or stacked on and secured by strapping, shrink-wrapping or other suitable means to a load board such as a pallet;*
2. *placed in a protective outer enclosure such as a pallet box;*
3. *permanently secured together in a sling.*

In accordance with section 10.18.2, packages that contain hazardous goods, that are permitted to be transported in accordance with the code, may only be transported in unit loads if the following conditions are fulfilled:

1. *It may occur that the packages in a unit load will need to be separated. In this event, it must be ensured that the individual packages can be handled safely.*
2. *The unit loads should be compact, have as regular a form as possible, and for the most part, vertical sides. The top of the unit load should be level. It must be possible to stack the unit loads. They must be constructed and secured in such a way that it is unlikely that the individual packages can become damaged.*
3. *The unit loads must be sufficiently strong to withstand repeated loading and stowing operations and they must be able to bear unit loads with a similar specific mass which are stacked on them to a height commonly occuring during transportation.*
4. *The material used to bind a unit load together must be compatible with the substances contained in the unit load and must remain effective under the influence of moisture, extreme ambient temperatures and sunlight.*

Palletization of plastic canisters contrary to regulations

Without the additional use of appropriate corner rails or cover boards, the straps alone will not be able to hold the plastic receptacles in place for very long. It is only possible to stack further unit loads on top of these with additional effort. When stowing the second or third layer, the goods stowed below must be protected from potentially damaging pressure by the use of additional measures.

Deficiencies can also be observed in the unit loads shown below:

Upper and lower images: Unit load with serious deficiencies

Changing proportions lead to increased freight costs since the outer dimensions are measured. If the pallet placed on top of these drums can be brought into the correct position, it will no longer be able to bind the load together securely. The tape wrapped around these cartons and the stretch wrap round the cases must be used correctly.

All in all, the only recommendation that can be made here is to separate the packages and load them individually.

Unit load with obvious deficiencies

If the lower pallet is intended to be part of the unit load then it should be firmly bonded to the rest of the load. That is obviously not the case here. Without the pallet, this "pack of three" cannot be handled by forklift truck and thus cannot be loaded rationally. The stretch wrap itself is unable to provide sufficient stability.

Less than perfect:
A unit load that is not flush

The benefits afforded by the efficient handling of unit loads are lost if gaps are left in the cargo. For the purposes of load securing, it would be more effective if each of the cases had been strapped separately.

Pallets should always be packed in such a way that the goods being transported, whether it be in cartons, sacks, pails, drums or canisters, are always flush with the pallet. Furthermore, only pallets should be used which are suitably dimensioned for the intended transportation method and the handling equipment that will be used.


Pallets that are appropriately dimensioned for transportation by truck

The trays containing empty cans are designed for use with the pallets used here. The pallets themselves are compatible with the dimensions currently used for road and rail vehicles, swap bodies and inland containers in Europe. Thus, two pallets can be loaded next to each other widthways or three pallets lengthways. For the purposes of overseas transportation, there are currently very few containers with an internal width greater than 2.4 m. Thus, these pallets are not suitable for transportation in overseas containers. The European transportation market now has a small number of CPCs or "Cellular Palletwide Containers".


Pallets that are not designed for the container

The packing receptacles are not designed for the pallet, and the pallets themselves are not designed for use with this container. This makes loading and unloading more difficult and increases the amount of securing that is required. The risk of damage also increases.

It would have been more sensible to use pallets or pallet-like bases sized 116 cm x 116 cm for transport in the container. This would have allowed two units to be loaded into the container next to each other in normal steel corrugated containers. The goods themselves should be packed in modular unit load packaging such as cartons, canisters, drums etc. which would allow a clean block to be formed on the pallet.

Telescope cartons with pallet-like bases designed for use in the container

Here the requirement for harmonized dimensions has been implemented and not just in terms of width, but also in terms of height. The telescope cartons fit tightly into the container and need no additional securing.

The stability of the cartons is, however, a possible point of criticism. Whether these are likely to survive the rigors of transportation is a matter of doubt. Interlayer dunnage with a large surface area would improve the situation. It may even be possible to support this dunnage for the lower and middle layer. If the contents are heavy it may be necessary to find out whether the four lengthwise slats on the pallet-like bases would cause pressure damage on the bottom of the cartons.

4.1.2.2 Unitization and palletization, Part 2

Continued from Section 4.1.2.1: The influence of faulty unitization and palletization on load securing

Load dimensioned to suit the internal measurements of the container

This example also shows that the dimensions of packaging receptacles can be designed to fit the internal dimensions of the containers themselves. Transportation modules of this type can help save costs.

Faulty unitization

The strapping as shown above is faulty. This method is unable to provide a stable unit load. The unpleasant tendency of corrugated drums to ride up over the corrugations can be prevented by appropriate unitization on pallets, but this will still not cure the tendency of pallets to ride up against each other.

Four drums with a maximum diameter of 585 mm can be stowed next to each other in standard containers. From the loading point of view, the most sensible option is to use drums with wide corrugations and a diameter of 580 mm, loaded onto pallets with dimensions of 1,160 mm x 1,160 mm.

Acceptable form of unitization

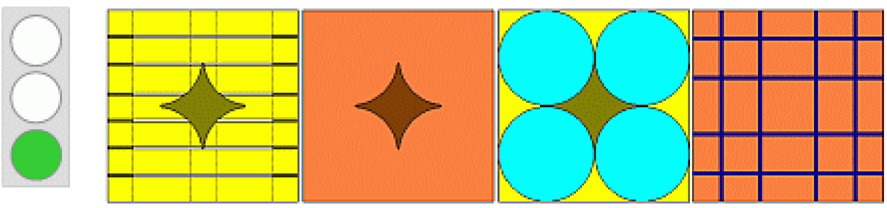
Formation of a unit load in the format shown above is acceptable, but its quality should not be overestimated. Since the strapping is vertical, it is unable to provide resistance to shifting. As a result, the top wooden board can easily shift. Diagonal strapping would be ideal but is extremely difficult to implement.

The picture below makes this problem clear.

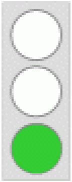
Diagonal shifting of the "lid" of a unit load

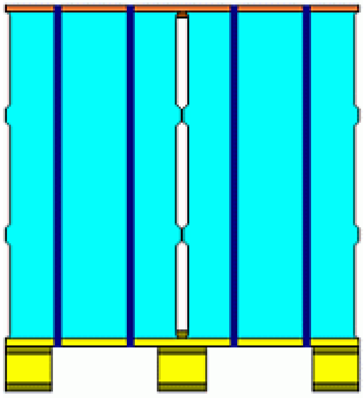
The "lid" used for this unit load is an inverted pallet. In this case, only two straps have been used for unitization but at least the drums were wrapped in shrink film first. Nevertheless: simply as a result of the transportation by road from the shipper to the container packing station, the "lid" has already shifted.

In series production it would make sense to affix a "lozenge" to both the pallet and the lid which would ensure a 100 % tight fit for the drums after strapping:



Pallet and lid with "lozenge" can guarantee a tight fit.





Side view of the strapped pallet

In order to reduce the risk of torn strapping, it would make sense to introduce pallets and lids which have grooves cut specifically to take straps.

Catastrophic unit load

This example also requires additional effort in order to guarantee that the plastic canisters reach the recipient in an undamaged state.

The pictures below provide particularly vivid examples of poor packaging and unitization: Wooden feet that extend beyond the pallet/or are higher than they are wide always cause problems during loading, packing and securing. The loaded surface area is too small and results increased loads on the cargo stowed underneath. Even experienced stowage and loading personnel can only partially compensate for this by using additional dunnage.

Note: It's a well-known fact that small feet, narrow and tall, are likely to collapse.

The use of steel strapping to hold packages in place should be avoided. The use of steel strapping without any edge protectors is particularly critical.

Unsuitable "feet" on packaging receptacles
Note: Stability comes when the wide edge is facing down.

Even the slightest of lateral forces are enough to collapse the feet of this plywood case. This combination package shows an "ALTO" arrow which simply indicates the top of the item, and not "transport this way up".

This selection of frequently observed packaging faults is just the tip of the iceberg. There is also a whole range of other weaknesses that indicate that the transportation of goods in general, and the packing of containers in particular, are operations that do not always run as smoothly as they could.

The requirement laid down in virtually all national and international legislation, regulations and agreements, namely that goods should be "packed safely" is unfortunately all too frequently not put into practice.

Very poorly wrapped unit loads

These unit loads have fallen apart when being transported from the warehouse to the loading ramp on the company premises - despite being very carefully deposited by the forklift operator.


Insufficiently wrapped carton on a Europallet

Companies very rarely respond appropriately and immediately when confronted with badly packed goods, despite the fact that they have the opportunity to do so.

Generally the shipper is responsible for all consequences caused by a lack of packaging or by poor quality packaging. In particular, the shipper is responsible for compensating companies for damage caused as a result of such faulty packaging.


Consolidated package that is unsuitable for transportation

A company which accepts goods for carriage that already show obvious evidence of damage is entitled to demand that an entry is made in the consignment note by the shipper documenting the state of the goods explicitly.


Load that is only fit for writing off

Pallets that are not loaded flush require additional securing. The badly applied steel strapping requires particular care when handling these loads using a forklift truck since they are easily torn away when applied in this manner. It is very difficult to assess whether or not the damage to the carton has also resulted in damage to the goods inside it or will do so subsequently.

If the lack of packaging/faulty packaging is not entered in the shipping documents by the shipper or the party delivering the consignment, then the company responsible for the onward transportation is required to document these faults.

Fit for writing off: Crates without sufficient diagonal bracing

Every wooden crate that does not have sufficient diagonal bracing should be classed as faulty packaging.

Fit for writing off: Crates without sufficient diagonal bracing

The lack of diagonal supports has already caused deformation of this wooden crate. Depending how sensitive the packed goods are, this deformation could cause damage. In addition, this example shows evidence of loading and securing errors.

Damaged chipboard pallet

As observations in many container packing stations have shown, pallets made of chipboard are not suitable for overseas transportation purposes. They are too weak and are very susceptible to damage. As a result of the very small surface areas of their feet, they also apply high loads to the objects they are standing on and can thus often only be used in conjunction with materials that are able to distribute this load.

The damaged feet of a chipboard pallet pose a risk to other goods.

Chipboard pallets are easily damaged even when subjected to very low loads. Both the sharp edges that remain and the reduction in surface area that results will further increase the loads on other cargo.

Insufficient wrapping of a chipboard pallet

Increased pressure as a result of small surface areas

Unsuitable solution to the problem

This pallet is too big for the carton. This causes gaps when packing the CTU. Since chipboard pallets are very sensitive to bending forces, the steel strapping may break off parts of the pallet. This means that the carton is no longer bonded securely to the pallet. In order to get around this problem, the carton and its pallet were loaded on their side. But this is not a particularly good solution because this can cause problems for handling staff and may even damage the contents.

Unit load that is not fit for transportation

Unacceptable unit load

Such badly packed pallets can only be loaded safely with a high outlay in terms of personnel and materials. The holes in the lower telescope carton indicate that an inexperienced forklift operator was entrusted with handling this pallet.

This unit load clearly shows the lack of understanding that has gone into unitizing the load. The consequence of this poor unitization will be that the packages will be split and loaded into the CTU individually.

In accordance with the IMDG code:
Load unit that contravenes the regulations

If a company is not prepared to load packages of this type individually, considerable effort must be put into correct load securing.

Unit load not suitable for transportation

With many packages, gaps remain when the packages are loaded next to each other. In other cases, the stretch wrap is too weak or does not form a firm bond with the pallets or other bases. Other unit loads cannot be stacked or have faulty strapping etc.

Above and left:
Faulty unitization hinders the correct packing of containers

Loads of this type make it impossible to pack the container tightly without additional work and materials.

Well packed unit loads are level and can be stacked. The ones shown here do not fall into this category.

The process of packing a container is made more complicated if unit loads are delivered which cannot be stacked. If unit loads are so heavy that they cannot be packed on the top layer or cannot be fitted into this space, then the packages must be split and loaded manually.

Faulty unit load

The faults are: No stable bond between the stretch wrap and the pallet base, the strapping cuts into the boxes, the surface is not level and thus does not allow anything to be stacked on top of it.

The sides of the unit load are not flush.

Since the sides of the unit load are not flush, additional work is required in order to fill the gaps.

4.1.2.3 Unitization and palletization, Part 3

Continued from Section 4.1.2.2: The influence of faulty unitization and palletization on load securing

According to the IMDG code, the unit loads should be compact, have as regular a form as possible, and for the most part, vertical sides. The top of the unit load should be level. It must be possible to stack the unit loads. They must be constructed and secured in such a way that it is unlikely that the individual packages can become damaged.

This unit load does not comply with the IMDG code

The requirements of the IMDG code have not been met. Nor have they been met by the following unit loads:

The main faults are:

No firm bond to the pallet, pallet is not loaded flush, unit cannot be stacked.

Load unit that does not comply with the regulations

Load unit that does not comply with the regulations

This pallet carrying hazardous goods is not packed flush. The bond to the pallet is not secure enough and there is a large gap in the top layer.

Irregularly shaped unit loads hinder packing work.

Unit loads that are as irregularly shaped as the one shown here make packing work more difficult. It may be necessary to split this unit and to load the packages individually.

The projection of the load beyond the edges of the pallet is a potential source of damage

One of the drums was already dented when the pallet was delivered by truck because the load extends beyond the edge of the pallet. Part of the strapping had become loose and the lid had shifted slightly.

It will only be possible to transport this load without damage by investing a considerable amount of effort for load securing. Since this load comprises Class 8 hazardous goods for maritime transport, this marks a violation of the law.

Loading gaps and faulty strapping increase the risk of damage.

The violation of the law is even more obvious here:


Insufficient strapping - no bond to the pallet

This cannot be termed a unit load. The drums must be loaded individually.

There are no bounds to some people's imagination when it comes to dreaming up methods of forming unit loads. The few pictures below should serve to illustrate the problem.





Damage is inevitable if loads are packed into a container in this state. Unless, of course, a huge amount of work and materials are invested during handling to repack, improve the packaging and to secure the load in place safely.

Violation of the unitization regulations

In place of the outlay required to unpack the pallets, dispose of the wrapping film, and to then pack the items properly and secure them in the container etc. it would possibly be worthwhile to procure a (used) box pallet or case and load the pails in that. It should also be borne in mind that such a breach of regulations would incur a fine if the authorities were to carry out an inspection.

Above and right:
Faulty formation of unit loads -
Violation of loading guidelines

These plastic drums also are not firmly secured to their pallet by the wrap. The gaps between the unit loads are an obvious violation of the regulations for the transportation of hazardous goods.

Incomplete strapping

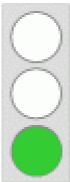
The strapping is missing on two sides and on the lower and middle sections of the load. The existing strapping is badly placed. The edge protectors used are only partially effective in this case and they are missing on the other two sides of the pallet. If the film that has been used is a shrink cover then the packers forgot to put the pallet in the shrink oven as well.

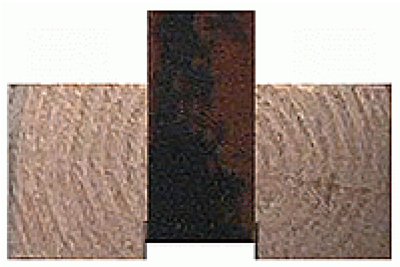
Unit that is unable to withstand a significant load

The use of weak packaging hinders the efficient packing of containers. Additional measures for damage prevention are required. Not only that, no edge protectors were used when strapping the load.

Rectangular dunnage placed on edge is liable to collapse.

This rectangular dunnage has been used incorrectly: Here a groove can been seen that has been cut specifically to take steel straps or plastic strapping in order to ensure that the strapping does not break or tear when it comes into contact with the floor. Used incorrectly as we can see here, the dunnage is likely to collapse. It is also increases the load on the surface it is standing on.





Correct use of dunnage

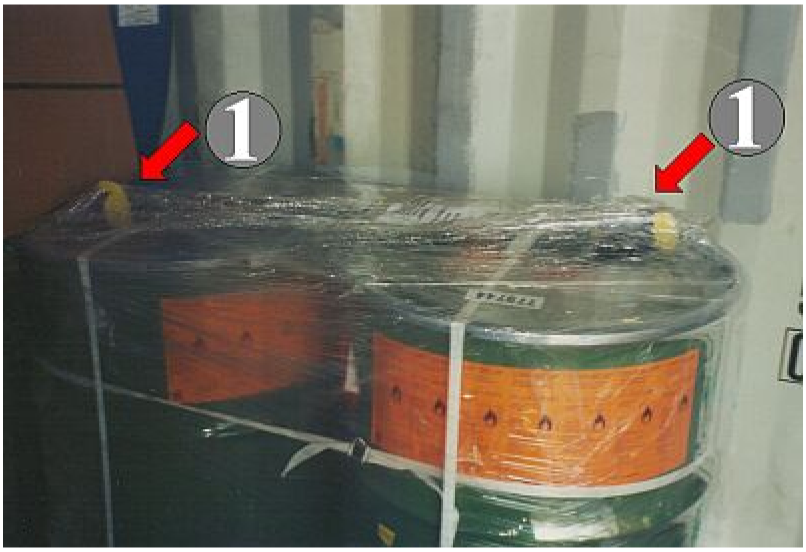
Incorrect use of dunnage

Risk of damage is increased when dunnage is used on edge.

The example given below shows the effort that must be invested in order to counteract the problems of faulty packaging and how unsatisfactory the ultimate solution is:

Above and left: Unit load that does not comply with the IMDG code

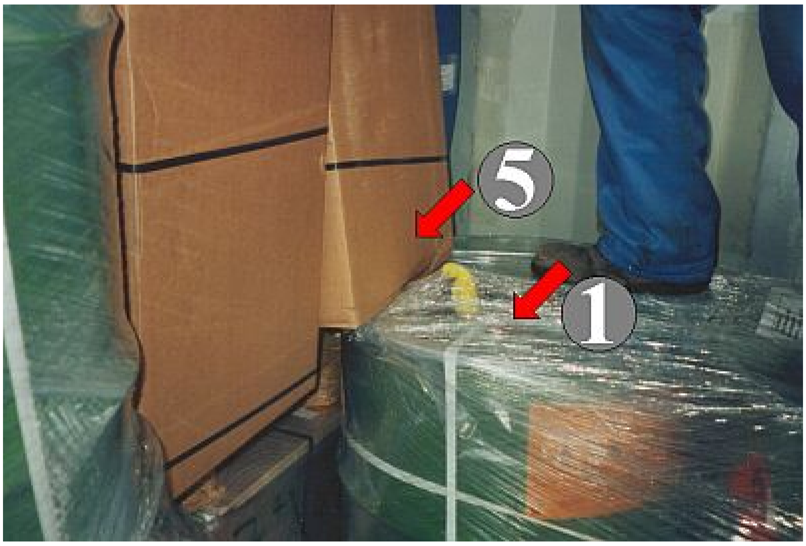
A number of mistakes have been made in packing this container: The pallet holding the drums has not been loaded hard up against the right-hand container wall. A wooden pallet has been placed vertically between the chipboard pallet and the drum pallet, but this does not fill the gap completely.



In violation of the regulations, this load surface is not even.

The drainage cocks for the drums (1) have been placed on top of the drums and stretch wrapped in place.

The only possible way of stacking other items on top of these drums would be to create a level surface using dunnage placed lengthways and then widthwise.



Risk of drainage cock being damaged by a packer standing on it

The gap behind the drum pallet must be filled in manually. Since the packer must ensure that he does not stand on the drainage cock, he is unable to handle the heavy carton (5) safely and it is distorted as a result of being accidentally placed on the edge of the drum.

The shrink-wrapped drainage cocks make packing work more difficult

The stowage gap above the drum pallet is only partially filled here. Behind package (3) there is a gap because the drainage cock of the second drum is located here.

Packing work is hindered by the shrink-wrapped drainage cocks

A gap has also been left for drainage cock (1) in front of package (3) and next to package (4). If the drainage cocks had been shrink-wrapped at the bottom of the drums, a wooden board could have been used as interlayer dunnage to allow the remainder of the stowage space in the container to be filled out more efficiently. It is correct and sensible to ensure that the hazardous goods drum pallet is packed in the vicinity of the container doors.

4.1.3 Securing goods in packaging receptacles

Badly constructed case

The basic idea, namely attaching a suitable base in order to stabilize a case that runs the risk of tipping, is in itself not a bad idea, but only if the package is to be transported on an open flatbed truck. It is unsuitable for use with a closed mode of transport. The case can only be secured with considerable effort, using wooden bracing or a considerable amount of material to fill in the gaps.

Lifting this object using a forklift truck from the side that can be seen in the photograph is only possible if the forks of the truck are very close together. Even a slightly uneven road surface could cause the case to topple from the forks. If the freight costs are calculated according to volume, money is being wasted since the dimensions used to calculate the volume are the extremities of the case.

It would have been more sensible to pack the contents into a stable case with a floor surface the same size as the special construction shown here. If the load is firmly bolted inside a case of this type, it can easily be packed into a closed CTU and secured. This method would not incur greater freight costs than the existing special construction.

Sometimes, the correct securing of the packed goods inside the packaging receptacle is overlooked.

Right and enlarged image below:
Insufficient securing of the load inside the receptacle

Even a sturdy box or case cannot ensure that the goods are not damaged in transit if the contents of the case are not securely packed. Here, the forces of inertia during road transport were sufficient to cause the load to penetrate the case.

Other notes about packing goods

For customs-related considerations, it is often advantageous to disassemble goods and transport them in cases or other receptacles.

Receptacle designed to accommodate two disassembled tractors

The practice is very often adopted when shipping cars. Terms like CKD and SKD meaning completely knocked-down cars and semi knocked-down cars, are used to describe vehicles that are packed in containers, crates and cases.

Wooden frame used for packing semi knocked-down sports cars into containers

4.1.4 Marking goods

4.1.4.1 Marking goods, Part 1

Experts are generally in agreement that the marking of the goods is an essential part of the packaging. This opinion is reinforced by a series of court judgments. For example, in a judgment by the Duisburg Landgericht (regional court) a company's claim for damages was rejected because the markings (handling symbols) necessary for safe handling of a package were missing.

The various domestic traffic regulations are almost unanimous in requiring that the shipper of a package mark this package in such a way that the marking is permanent, clearly visible and cannot be confused. The markings must correspond to the specifications in the consignment note. All old addresses and labels must be removed or clearly negated. In some areas, it is also necessary to specify both the shipper and the recipient.

Part 1 of the current DIN standard 55 402 entitled "Shipping marks for packages" describes the pictorial markings for the handling of goods, and Part 2 provides a directive for export packaging. Adherence to such standards should ensure uniform marking of the packages to be shipped. The standard does not apply to advertising and required information that is regulated by the guidelines of various transport service providers, such as the postal services, the rail services or by individual countries. Further information can be found in ISO/DIN 780.

Markings should always be restricted to the necessary information. They should be applied without a border, and must be easily legible and permanent. They must be able to withstand the rigors of transportation.

Black should be used if possible. It must, however be ensured that the markings contrast with the color of the package. Where adhesive labels are used, the standard recommends black printed on a white background. The colors not permitted by the DIN standard are those that are reserved for hazardous goods, for example, orange and bright red.

The hazardous goods regulations previously demanded that a border was placed round the symbol. This is no longer the case.

If goods are relabeled, both the pictorial marks and the lettering of the old markings should be made illegible. This is intended to eliminate all risk of errors and misdirection.

The specifications in the shipping documents must match the specifications on the packages themselves. The problem for the practitioner here is that even if an incorrect or incomplete marking is applied, they are not permitted to correct the markings or add markings without authorization. Otherwise this could lead to problems with customs, foreign trade banks and similar interested parties.

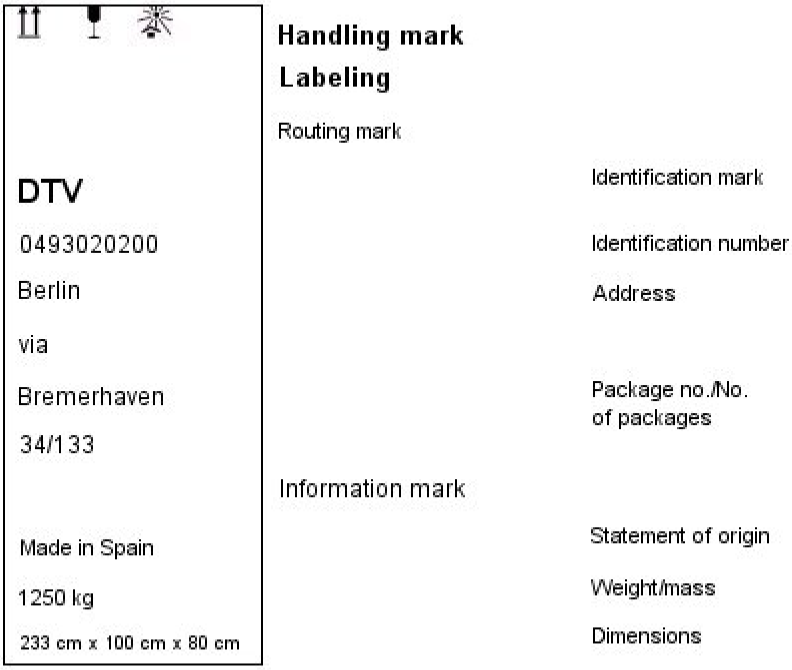
Those who are responsible for the packing and labeling of goods must be familiar with the various standards, or have them available for reference, and must act in accordance with them.

For those who "only" deal with the transportation of the packages, it is important that they are able to read and interpret the markings on the packages and not that they should be able to attach or modify these markings.

Labeling in accordance with the standards

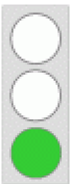
According the various standards, the labeling is to be made up of the following items of information. The sequence should be adhered to unless special directives apply for particular circumstances.

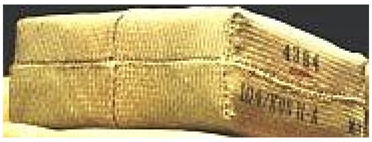
Example of a marking that conforms to the standards:



The shipping mark and the statement of origin should be arranged one below the other. The weight and the dimensions should be applied to the bottom right of the package, and handling information preferably to the top left.

For cuboid packages, the handling information and the markings should not be separated. They should be applied to at least two adjoining sides. The only exceptions to this rule are pictorial markings that are tied to a specific location, for example, those showing the center of gravity. For cylindrical objects, it is sensible to apply the labeling to two opposite sides. It is sufficient to mark bagged cargo and bales on one side only.





Marking on a bale of tobacco from Indonesia

Incorrect marking: Handling information and marking are separated

Incorrect marking and design

The pair of arrows should have been on the front of the crate. All marking should also have been duplicated on an adjacent side. A comment on the case: It is constructed in such a way that the lid boards can lift easily if slinging equipment with multiple cables and a single hoisting point is used. Here, either metal corners should be used or the lid boards should be recessed or rabbeted. The air vent protrudes by approximately 1.5 cm. This may be torn off or may damage other goods during packing.

Information that is not required for shipping should not detract from the effectiveness of the markings. They should thus not be applied to the same sides as the markings.

Unless otherwise specified in other regulations, all markings are to be effected using Arabic numerals and in capital letters. The size of the letters will depend on the amount of space available and is specified in the standards. Clarity and legibility must be ensured. The letters and numbers of the shipping mark should contrast with other markings. All letters and numbers should, however, be smaller than the specified handling instructions.

Markings that do not comply with the standards

Here, neither the size nor the location of the labeling meet the requirements of the standards.

Unfortunately the existing regulations are rarely applied in practice. In the event of doubt about the meaning of a marking, information should be obtained as soon as possible from experts or from the persons/institutes responsible. This is particularly important for hazardous goods markings as well as the sling here and center of gravity markings.

Shipping mark

The shipping mark of a package includes the identification mark, the identification number, the address and the total number of packages in the consignment, as well as the sequential number of the package within the consignment.

Identification mark

The identification mark may be the first few letters of the name of the shipper or recipient or the company name of the recipient.

Identification number

The identification number may be, for example, the order number, consignment note number or bill of lading number among other things.

Address

If the package is to be received at a port, the name of the port only should be specified. If the package is to be transported further once it has reached port, then the address should be specified as the destination via the destination port.

Total number of packages in the consignment, sequential number

The total number of items in the consignment must be specified plus the sequential number of the package within the consignment.

Information markings

Information markings include information about the country of origin, and the weight and dimensions of the package.

Statement of origin

The statement of the origin must be in accordance with the requirements of the relevant countries. The statement of the country of origin is often mandatory. In some cases, however, it is not desired.

Weight

As of a gross weight of 1,000 kg, packages must display weight information. With regard to ease of transport, handling and storage, however, the relevant standards also recommend indicating the weight in lighter packages.

Dimensions

The standards state that the dimensions of a package should be specified in centimeters.

Handling symbols

In order to guarantee the correct handling of packages and goods, pictorial symbols are used. The use of textual information to enhance the pictorial symbols should be avoided.

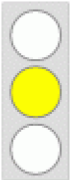
The pictorial symbols are to be applied without a border. In the past, the hazardous goods regulations required the use of pictorial symbols with a border to identify hazardous goods. This is no longer the case. The authorities will generally tolerate a border if there is one.

Meanings of the pictorial symbols according to DIN, ISO and IEC

The German meanings of the pictorial symbols in accordance with the German standards and the English meanings as defined by the International Organization for Standardization and IEC are described in the following section.

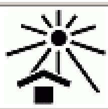
Symbol	Meaning according to DIN	Meaning according to ISO
	Keep dry	Keep dry

Since goods of this type should also be protected from high levels of humidity, they must be transported in closed vehicles or containers. If it is only possible to transport particularly heavy or bulky goods on platforms, flats or in open top containers these must be covered carefully using tarpaulins.

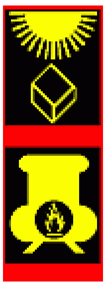


Tarpaulin-covered case with the umbrella symbol

Load securing issues will not be discussed here (although the securing could be improved). The important consideration is that the cover must be water-tight and that it is not possible for condensation to form below the tarpaulin. This can only be achieved with considerable effort. More information and hints about using tarpaulins can be found elsewhere. The cover must be as securely lashed as possible to make sure that it cannot be detached or destroyed by stormy conditions.

Symbol	Meaning according to DIN	Meaning according to ISO
	Protect from heat - But also: Protect from sunlight	Keep away from heat

In order to comply with the requirements of this symbol, goods traveling to certain climatic regions can be loaded into insulated containers or vehicles, or at the very least, an appropriate distance to the vehicle or container walls and roof should be maintained. Remember: Any gaps must be filled in.
When goods are imported from abroad, symbols are often used which are not ISO-compliant. In the vast majority of instances, these symbols can be understood by the storage and handling staff and leave little room for misinterpretation.

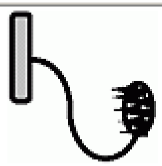


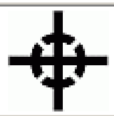
The Chinese symbol for "Keep away from heat"

Here, the sun as a source of heat is easy to recognize. Identifying the second symbol as a source of heat is somewhat more difficult.

Symbol	Meaning according to DIN	Meaning according to ISO
	Use no hooks	Use no hooks

Any other kind of point load should also be avoided with goods marked with this symbol. However, this symbol does not ban the so-called plate hooks that are sometimes used to manually move appropriately marked, robust, bags made of natural materials such as sisal, hemp, jute etc.

Symbol	Meaning according to DIN	Meaning according to ISO
	DIN does not recognize this symbol	ISO does not recognize this symbol
	Internationally understood meaning	
	Plate hooks may be used	

Symbol	Meaning according to DIN	Meaning according to ISO
	Center of gravity	Center of gravity

This symbol is intended to provide a clear indication of the position of the center of gravity. It only makes sense to use this symbol if the center of gravity is not in the middle of the object. If there are no symbols giving the location of the center of gravity, the warehouse and handling staff can safely assume that the center of gravity is in the middle of the load.

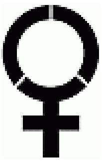
Unnecessary center of gravity marking

If a load with a center of gravity which is not the middle of the object is not marked up accordingly, the shipper/packer of the load can be held responsible in the event of accidents or damage.

The center of gravity is clearly identified if the symbol is applied to two adjacent sides (at right-angles). The DIN standard, however, recommends that it be applied to three surfaces, namely two adjacent sides and the top. This is particularly relevant for large and heavy packages as the operator of the lifting equipment is then also able to see that the center of gravity is not in the middle of the package.

Marking the center of gravity on three sides of a load, in accordance with the DIN standard

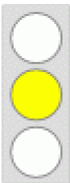
Exports destined for countries of the former Soviet Union should use the Russian symbol for the center of gravity. There, the cross is placed below the circle.

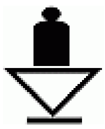


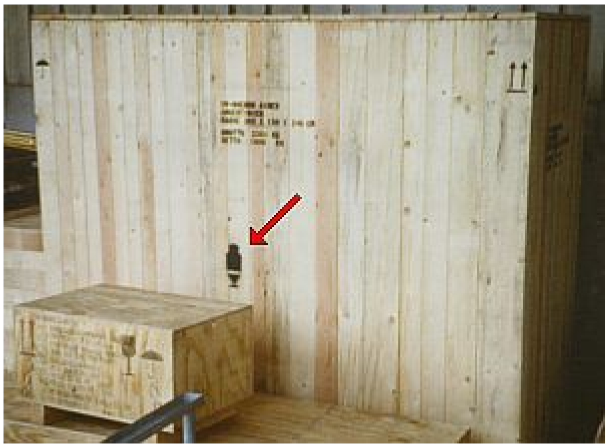
Russian symbol showing the center of gravity

Containers with a center of gravity that is outside the specified tolerance of ± 2' (≈ 60 cm) for 20' containers and ± 3' (≈ 90 cm) for 40' containers must always be marked with the center of gravity symbol. Permits must also be obtained from the transportation and handling companies with regard to the special location of center of gravity.

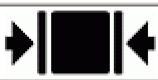
For some decades now, the DIN standard has not included the "top-heavy" symbol. This was symbolized by a weight balanced on an inverted triangle. It formerly had to be used for objects with a center of gravity above the middle of the object. As can be seen from this picture (taken recently) the information that this symbol should no longer be used has not yet reached all shippers.



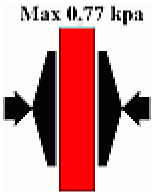




Package showing the outdated "top-heavy" symbol

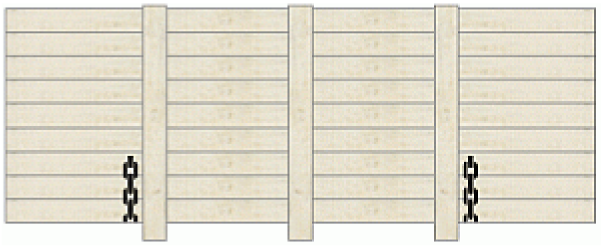
Symbol	Meaning according to DIN	Meaning according to ISO
	Clamp here	Clamp here

The statement that the package may be clamped at the indicated points is logically equivalent to prohibiting clamping anywhere else.

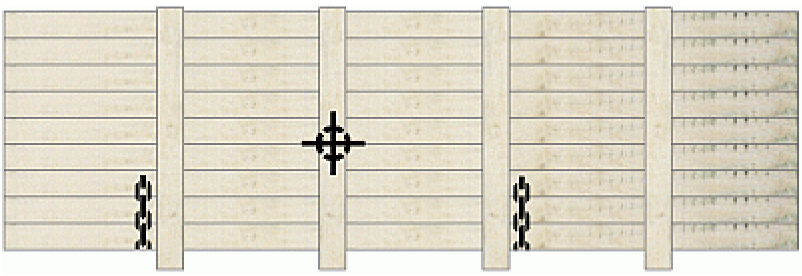
Symbol	Modified symbol as used in practice
	Only clamp with the specified pressure

This is a very useful piece of information in practice. The example gives the specified maximum pressure as 0.77 kPa (kilopascal) or 7.7 hPa (hectopascal) or 0.00077 MPa (megapascal). Expressed in the unofficial, yet still widely used units of pressure, this is 0.0077 Bar or 0.077 kg/cm² or kp/cm². For handling staff, the specification 0.077 t/m² may also be helpful.

Symbol	Meaning according to DIN	Meaning according to ISO
	Sling here	Sling here

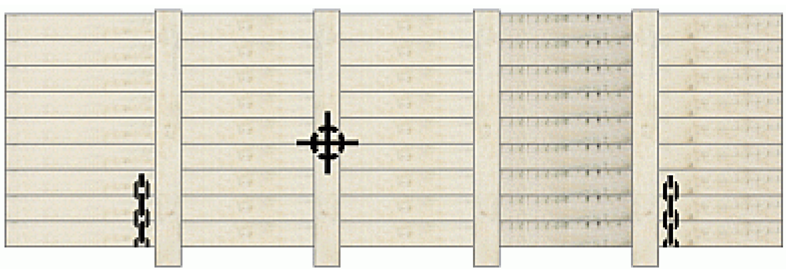


Case with a center of gravity in the middle of the load



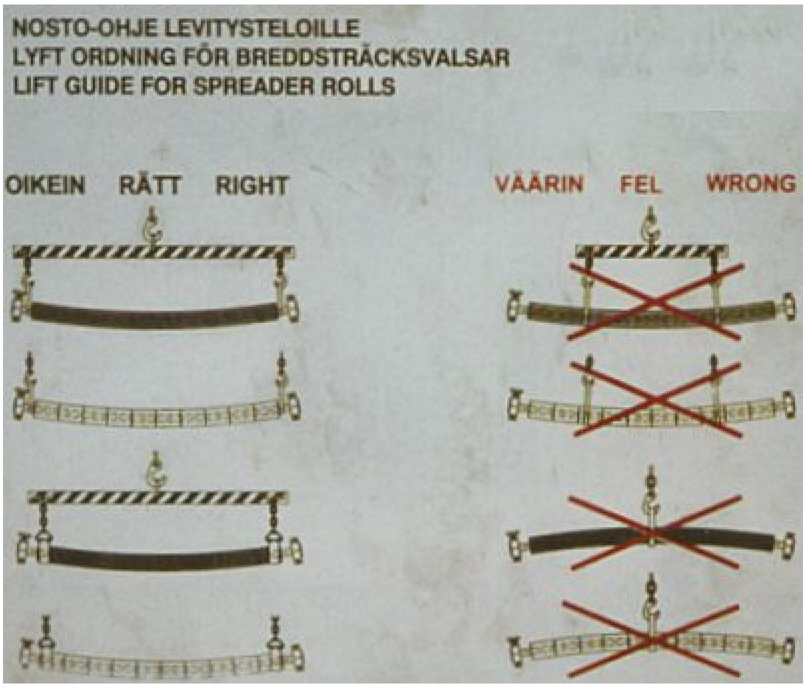
Case where the center of gravity is not central

If the "sling here" symbols for a load with a central center of gravity are equidistant from the middle or are equidistant from the center of gravity for an off-center load, then the package will be level when suspended if slinging equipment of the same length is used.



Case whose center of gravity is not central and with asymmetric slinging instructions

If this is not the case, the slinging equipment must be shortened appropriately where the distance to the center of gravity is shorter. If one were to attempt to use slinging equipment of the same length the case would not be level. Thus, in the example above, the case would tilt considerably to the left and may fall.

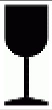


Additional slinging information using special markings

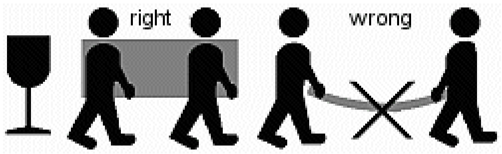
With certain goods that must be slung in a particular way, it makes sense to provide warehouse and handling staff with additional information to help them handle the object properly. The example shown here is easily understood.

4.1.4.2 Marking goods, Part 2

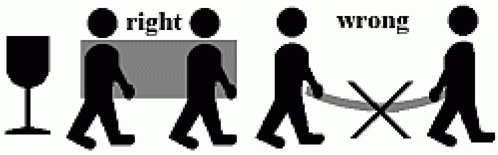
It is may also be sensible to include information about restrictions on the maximum amount a load may be tilted or indications that the load is not to be tied.

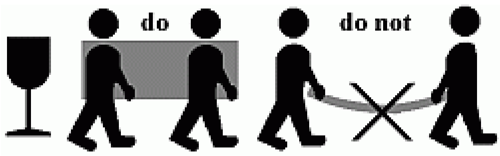
Symbol	Meaning according to DIN	Meaning according to ISO
	Fragile, Handle with care	Fragile, handle with care

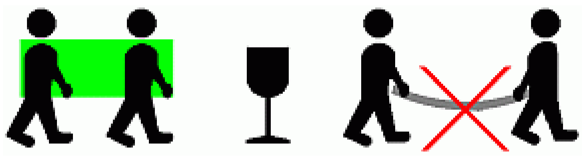
This symbol is used for fragile goods. Goods marked with this symbol should be handled carefully and should never be rolled over or tied tightly. In the case of certain hazardous goods, packages of this nature should have anything stacked on top of them. More information about this can be found in the General Provisions of the relevant regulations or in the special notes for the various classes or special goods.

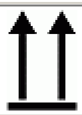
Symbol	Proprietary symbol developed by a German glass manufacturer
	Meaning: Object should only be carried on edge

This symbol can be clearly understood by anyone. When used abroad, the German "RICHTIG" and "FALSCH" can be replaced by English text, for example, "RIGHT" and "WRONG" or "DO" and "DO NOT", or colors and a clear X symbol could also be used to indicate the correct/incorrect method.







Symbol	Meaning according to DIN	Meaning according to ISO
	Top	This way up

The package must be stored, handled and transported in such a way that the arrows always point upwards. Rolling, swinging, severe tipping or walking of goods marked in this way must be avoided. It has been suggested that the meaning of this symbol is changed to to "transport upright" or "keep upright" in the next edition of the DIN standard.

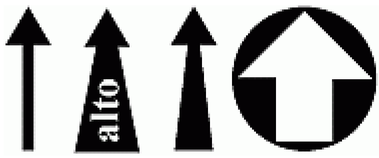
Pallet box and the appropriate handling symbols

The green traffic light indicates that the package is marked correctly. However, the red traffic light and the red arrow indicate that the marking has been applied at an inappropriate location and that the package has already been damaged by incorrect handling. The strapping used is not suitably placed for handling with a forklift truck.

Corrugated board carton standing and on its side

If a package does not have this pair of arrows, it may be handled or transported lying on its side or even upside down, which could damage the contents.

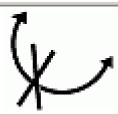
The pair of arrows does not mean that an object must be stowed on the top layer nor do they mean "open here". The latter of these two meanings is indicated by a single arrow or other similar symbol:



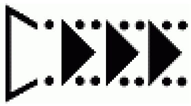
A package that is marked with an arrow like the ones shown does not have to be transported upright. The correct symbol should clearly indicate the intended meaning. However applying all sorts of nonsensical symbols is a practice that should be avoided. One can only really expect long-term observance of the handling symbols if they are used sparingly and sensibly.

Incorrect choice of handling symbol

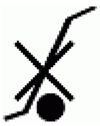
The shipper of this case probably wants it to be transported upright. But this is not what the symbols mean. It is also better to apply the handling symbols next to each other and on two adjacent sides.

Symbol	Meaning according to DIN	Meaning according to ISO
	This is not yet incorporated in the standard	Do not roll

The package may not be rolled, swung, or tilted to any great degree during handling. The symbol should always be observed, despite the fact that it is not included in the German standard.

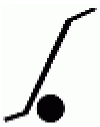
Symbol	Meaning according to DIN	Meaning according to ISO
	Tear off here	Tear off here

This marking is intended only for the receiver. Generally speaking, warehouse and handling staff should not open packages.

Symbol	Meaning according to DIN	Meaning according to ISO
	No hand truck here	No hand truck here

If this symbol is missing on one or more sides of a package it is assumed that the hand truck may be used on the unmarked sides of the package.

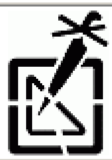
Although the "hand truck here" symbol does not officially exist, a symbol of this nature is often used.



Meaning: Hand truck here

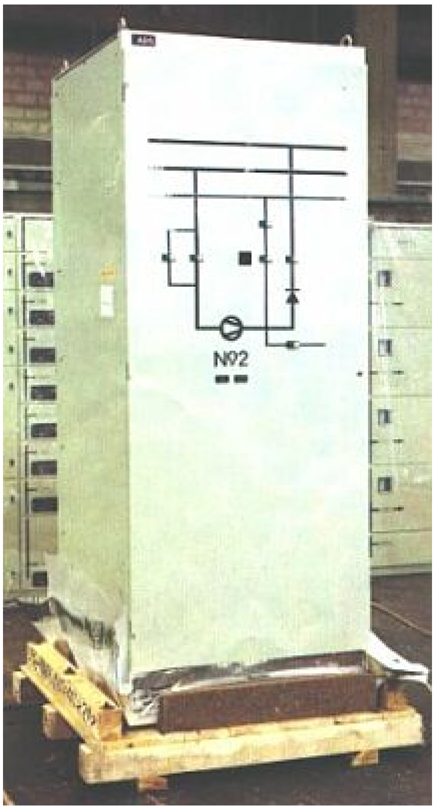
The use of this symbol to provide staff with clear information is to be welcomed. Thus, for example if a carton containing a refrigerator may be moved by hand truck from two sides, but not from the other two sides, then it would make sense to use both of these symbols and apply them to the relevant sides.

Left side of the refrigerator	Hand truck here
Door side of the refrigerator	No hand truck here
Right side of the refrigerator	Hand truck here
Rear of the refrigerator	No hand truck here

Symbol	Meaning according to DIN	Meaning according to ISO
	Do not destroy barrier	Do not destroy barrier

A barrier layer which is (virtually) impermeable to water vapor and contains desiccants for corrosion protection is located beneath the outer packaging. This protection is no longer afforded if the barrier layer is damaged. Since the corresponding symbol has not yet been approved by ISO, puncturing of the outer layer should also always be avoided for any packages bearing the words "Packed with desiccants".

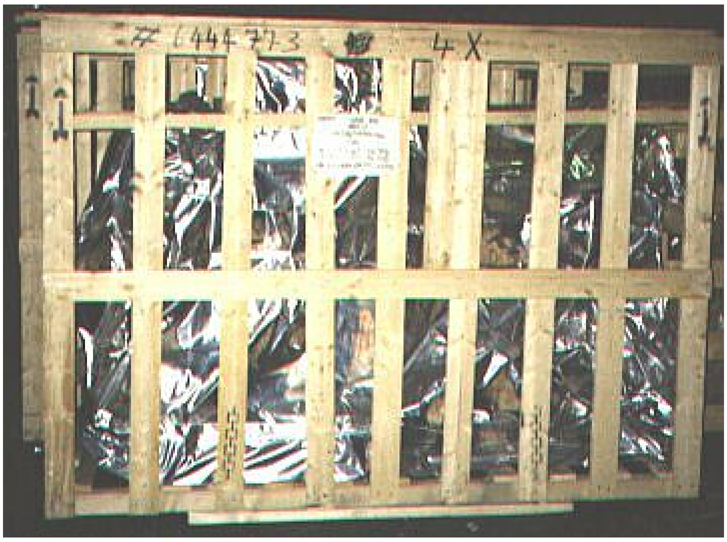
For example, the handling symbol described should be applied to this package.



Above and left: Packaging for a control cabinet

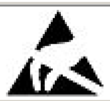
Depending how sensitive the goods are, the length of the journey, the climatic conditions, the onward carriage and standing time of the goods, the appropriate form of conservation should be employed. Goods can be protected from corrosion using coatings, spraying, painting, dipping, desiccants, volatile corrosion inhibitors (VCI method) and other effective measures. Attention should be paid to all critical issues before doing so. If in doubt, advice should be obtained from professional packers, or the job should be handed over to a reputable packing company.

Sealed packages, and in particular those in which desiccants have been included, should not contain hygroscopic materials. Packages of this nature should be carefully protected from damage.

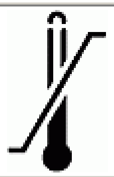


Badly constructed and marked wooden crate

The lack of diagonal bracing can lead to the crate becoming deformed and thus causing damage to the contents. The symbols indicating a sealed package are missing. This can easily be damaged during handling. A case would have been a more suitable receptacle. The single arrows do not oblige the handling staff to keep the crate upright at all times.

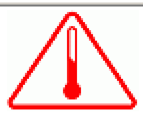
Symbol	Meaning according to DIN	Meaning according to ISO
	Electrostatic sensitive device	Electrostatic sensitive device

Touching parts that are marked like this under relative humidity conditions of less than 70 % should be avoided if wearing electrically insulated shoes or when standing on a insulating surface. Low levels of relative humidity must in particular be expected on hot, dry summer days and very cold winter days.

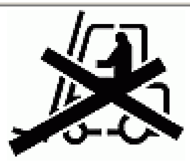
Symbol	Meaning according to DIN	Meaning according to ISO
	Permitted temperature range	Temperature limitations

According to the regulations, the symbol should either have an additional °C for a single temperature or °C max. and °C min. to give the upper and lower temperature limits of a range. The relevant temperatures or temperature limits should also be noted in the shipping documents.

Transportation of goods that are marked like this is generally carried out using refrigerated containers or vehicles, or at the very least, insulated containers or well insulated vehicles.

Symbol	Meaning according to the hazardous goods regulations
	Temperature-controlled load

The symbol for temperature-controlled cargo has been included in the hazardous goods regulations for a number of years. The relevant hazardous goods regulations provide information about the necessary markings and their meanings.

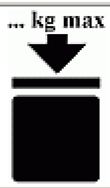
Symbol	Meaning according to DIN	Meaning according to ISO
	Do not use forklift truck here	Do not use forklift truck here or: Use no forklift

This symbol should only be applied to the sides of a package where a forklift truck cannot be used. Absence of the symbol on other sides of the package amounts to permission to use forklift trucks on these sides.

The following symbol is not part of either the DIN or the ISO regulations, but is sensible and should be used as required.

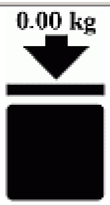
Symbol	Unofficial meaning
	Use forklift truck here or: Forklift here

A sensible combination of these two symbols would be, for example, on a long case that as a result of its construction can be lifted with a forklift truck from its long sides but not from either of the ends. However, other combinations or variations are possible.

Symbol	Meaning according to DIN	Meaning according to ISO
	Stacking limitation	Stacking limitation

The stacking limitation should be specified in kg. Since a marking of this nature is only ever applied to packages that are able to take very little load, these are usually goods that are packed in the upper layer.

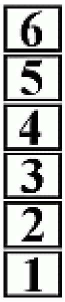
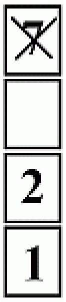
If the limit is specified as 0.00 kg it should be clear to both warehouse and handling staff that the goods may not have packages stacked on top of them.

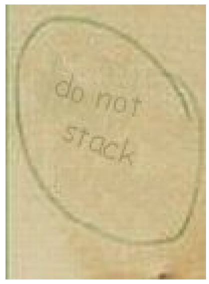
Symbol	Recommended use with the following meaning
	Only transport in the upper layer or: Top layer or: Do not stack

The recommended use of the symbol should be clearer than any proprietary labels:

The phrase "Bitte nicht belasten" will be clearly understood by German-speaking staff to mean that the package should not be subjected to loads. "Fragile" on its own is no guarantee that other items will not be stowed on top of this package. The marking "Please do not load" is more likely to cause confusion, as it is not clear what is meant.

For the carriage of homogenous loads, the industry has developed a number of its own symbols which are very clearly understood and refer to the number of layers or tiers that may be formed using certain packages.

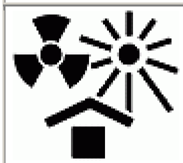
Symbol		Meaning
		Only stack six layers high



Cargo is at risk if the handling symbols are missing.

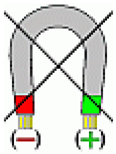
If this case should not be stacked, it would be better to use the appropriate symbols instead of writing "do not stack" by hand, in German on the case. The hazardous goods regulations state that the markings on a package should be applied in such a way that they are guaranteed to survive three months exposure to sea water.

The required hazardous goods markings and their meanings can be taken from the appropriate regulations. General notes can also be found in the appropriate sections of the CTU guidelines.

Symbol	Meaning according to DIN	Meaning according to ISO
	Protect from heat and radioactive sources	Protect from heat and radioactive sources

Since the term heat is not clearly defined here, the packages should be stowed in as cool a location as possible. In addition to this, sensitivity to the temperatures that can be expected should also be checked. The presence of radioactive sources should in theory be known as a result of adherence to the regulations or as a result of the correct labeling of packages and receptacles. If refrigerated containers or refrigerated vehicles are not to be used, it is recommended that at least insulated containers or vehicles are used. Under no circumstances should loads of this type be stacked close to the walls or roofs of normal containers or vehicles.

Certain packages such as computers and accessories, may not be exposed to magnetic fields. The industry in many countries has developed easily understood symbols to indicate this. Here is an example:

Symbol	English meaning	
	Do not expose to magnetic fields	

Further information

When transporting items such as steel bars and pipes, for instance, the labels are very often in the form of sheet metal tags that are hung on the cargo. When handling loads of this type, it must be ensured that these tags do not become detached, as this could lead to problems with customs authorities or incorrect delivery. If a tag of this type is detached or such a detached tag is found, it must be taken to the appropriate office or person.

German terms

Markierung von Gütern	marking of shipping goods
Markierung von Gütern	kind of lettering
Bestimmungshafen	port of destination
Kollo, Packstück	package
Bestimmunsgort	port of destination
Ursprungsland	country of origin
Gewicht	weight
Abmessungen	dimensions
Marke; Märk	mark
Kollianzahl	number of pieces/packages
Kollonummer	package number
markieren	to mark
Leitmarke	guide mark
Kennmarke	identification mark
Kennmarke	registering mark
Volumen	volume

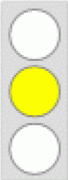
4.2 Packing and stowage methods

4.2 Packing and stowage methods

Unlike the transportation of general cargo on conventional ships, containers represent small, closed loading areas or loading platforms of a specific dimension. The first definition applies primarily to box containers, whereas the second applies to platform containers. The height and width dimensions may be exceeded to a certain degree.

"Stowage methods" is still a frequently used term in the industry. But the use of containers and other cargo transport units (CTUs) demands further distinctions in the use of terms, because not only do the CTUs themselves have to be loaded and unloaded but also, the containers have to be positioned on land or on various means of transport. It is therefore necessary, for regulations such as the CTU guidelines, to define terms to distinguish between the various activities. The "Definitions" sections includes the following:

***Packing** means the packing of packaged and/or unitized or overpacked cargoes into CTUs.*



Packing/stuffing a container **Packing a semitrailer**

Terminal staff often refer to "stuffing" the containers in this context. It is often also carried out at "packing centers". It is essential that all dead space in containers is filled.

***Unpacking** means the removal of cargo from CTUs.*

Unpacking/stripping an import container containing coffee bags

Terminal staff often refer to this activity as "stripping".

***Stowage** means the positioning of packages, IBCs, containers, swap-bodies, tank containers, vehicles or other CTUs on board ships, in warehouses and sheds or in other areas such as terminals.*

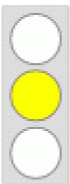
Stowage on board a full container ship

Container stowage on land

It should be obvious that every container load needs to be packed carefully. Where necessary, packing should be supplemented by appropriate load securing measures:

Unfortunately, not everybody thinks that the need for careful packing is obvious.

Here we see household effects which were not stowed properly.



It is often difficult to pack carefully.

Here we can see commercial goods. Packages with different dimensions often present the packing staff with problems which are difficult to resolve. If the dimensions of the packages do not meet the requirements of modularity, any gaps which remain must be filled in rigorously.

Inspecting an outgoing container

On arrival in port, random checks are occasionally performed to ensure that a load has been packed and secured correctly. However, these checks are mainly limited to a small number of containers carrying dangerous goods. They are arranged or performed by the harbor police or by the shipping company. It is unusual or even impossible for a load to be checked or corrected during a sea voyage. Loading and securing must therefore always be performed correctly. Stowage and securing errors made prior to acceptance of the container or which arise during the voyage can thus have more serious consequences than errors with a non-containerized load. Time is also a significant factor: On a long sea voyage, even minor initial deficiencies can develop into serious losses. The proportion of containers considered inadequate is alarmingly high. Around 70%!

There are a number of national and international regulations relating to shipping and transport which provide important guidelines on how to handle and package goods, as well as how to pack and secure them. These legal stipulations are supplemented by a number of civil-law regulations and contracts, in particular special conditions for individual means of transport. Further information can be found in the recommendations of special organizations or various companies. Loads can only be transported safely around the globe by observing some fundamental issues. The only way to prevent damage from arising is by packing and unpacking in a professional manner and by using appropriate packing and securing methods. All preparation and final work must be fully integrated in operational organization procedures. The remaining units in this section of the Container Handbook address and explain a number of important issues.

4.2.1 Preparatory work

When producers pack their own goods into cargo transport units, they should do so with trained staff and sufficient expertise.

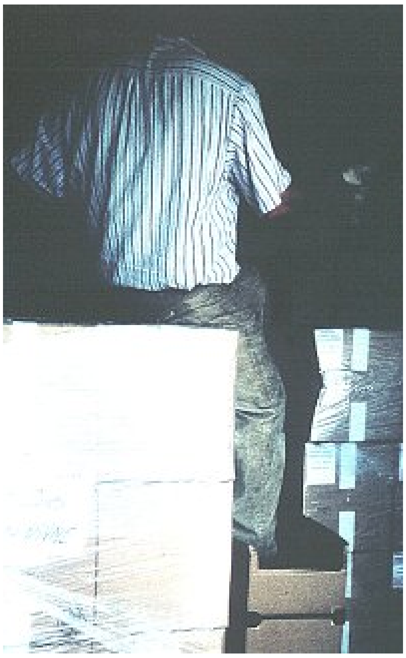
If external companies are entrusted with the storage, handling or transport of goods, they must fulfill their duties as carefully as if they were dealing with their own goods. They must ensure that nothing is spoilt or damaged and that articles and materials entrusted to them cannot have a damaging effect on other goods or on the environment.

This obligation to exercise due care entails an important principle concerning the provision of suitable storage areas and handling and transport equipment:

> *Open or closed areas intended to receive goods must have facilities and characteristics suitable for transporting or storing these goods. They must be in a state or be brought into a state which allows correct and safe transportation.*

Port operation with all the facilities required for correct transportation

This results in a series of **obligations and activities** for all staff involved in the supervision, storage, handling and transport of goods to ensure smooth shipment of those goods. These include, most importantly, the accurate planning and sophisticated organization of all processes. Otherwise, errors can propagate to every area of goods handling.



"Trampling" on packages must be strictly forbidden.

Good organization involves not only clear procedural instructions but will also ensure that these instructions are observed and monitored and that the staff receive regular training.

This section provides a brief summary of important preparatory work. More detailed information on some of the specific issues outlined there will be found in separate sections. The actual work procedures and final work is dealt with in separate sections.

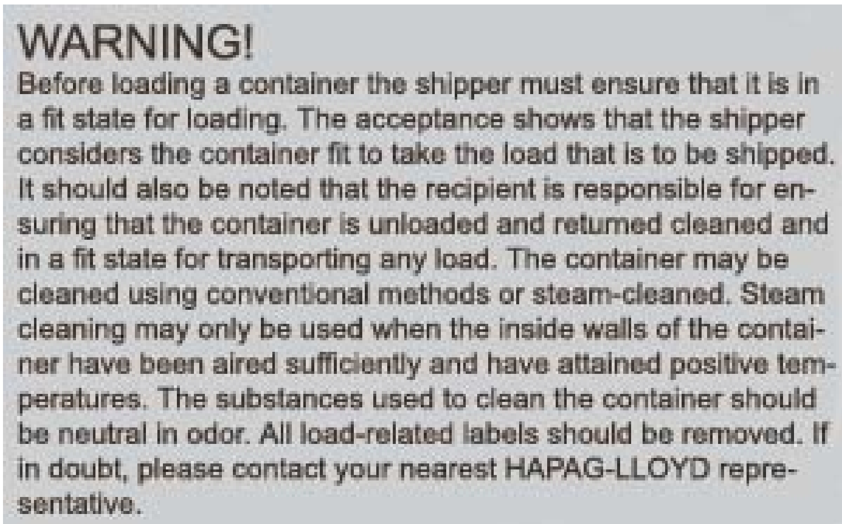
Preparatory work for the orderly acceptance or handing over of a load includes particularly the following tasks:

The **selection of suitable facilities for storage, handling and transport of goods and adequate stowage and storage space** is the particular task of all persons involved with the logistics for vehicles, containers or devices, and of shed or warehouse managers. They must ensure that suitable means of transport, ground conveyors and other equipment are available in the right place at the scheduled time. Outdoor short and long-term storage areas, covered hangars, sheds and warehouses should be marked out beforehand and dedicated to receiving specific goods. Staff under instructions have little influence in these considerations. Exceptions to this arise if staff are permitted to freely select from a series of empty containers. The loading staff in ports have no influence on the stowage locations for CTUs on board ships. These locations are specified by the stowage centers of the shipping companies or by the shipmasters.

Checking or establishing fitness for loading is an important prerequisite for being able to begin packing. Irrespective of the type of cargo transport unit used, fitness for loading must be established. The same also applies for short and long-term storage areas. They also must be in an adequate state to allow the goods to be stored safely and without damage. If this is not already the case, they must be brought into this state. Different properties of the different goods which constitute a load necessitate different requirements. Only a few general principles will be dealt with here. Although some concessions can be made under certain circumstances, they will also have to be supplemented by further measures under other circumstances. The term "fitness for loading" implies that work can be begun without delay. It may be necessary to line or pad out the floor of the area with boards, planks, squared lumber etc. It must be possible to handle the goods by lifting gear or ground conveyors without difficulty.

This step on the threshold presents a risk for staff, equipment and load

Fitness for loading also means that permitted stacking loads, wheel loads or axle loads are (can be) observed. Otherwise, the result could be damage to vehicles, stowage or storage areas or the goods that make up the load. Sometimes, the permissible load stated is clearly visible. Sometimes, it can easily be ascertained. In some cases, it must be taken from the relevant regulations.



WARNING!

Before loading a container the shipper must ensure that it is in a fit state for loading. The acceptance shows that the shipper considers the container fit to take the load that is to be shipped. It should also be noted that the recipient is responsible for ensuring that the container is unloaded and returned cleaned and in a fit state for transporting any load. The container may be cleaned using conventional methods or steam-cleaned. Steam cleaning may only be used when the inside walls of the container have been aired sufficiently and have attained positive temperatures. The substances used to clean the container should be neutral in odor. All load-related labels should be removed. If in doubt, please contact your nearest HAPAG-LLOYD representative.

Notice in a container

The degree to which a container must be **clean** must always be considered in relation to the particular goods to be stored or transported. The requirements for stowage space and holds will naturally differ for coffee, spices and other foods and foodstuffs compared with, for instance, granite blocks, steel, machine parts or hazardous materials.

Notice indicating that the container has been cleaned

The minimum requirement is that the stowage space is **swept out**:

Not swept out, and even traces of moisture

In this context, it is important not only that the floor is swept out, but also that any other dusty or contaminated parts, such as side and end walls, doors, roofs, covers, stanchions etc. are cleaned appropriately. Basic cleaning can prevent not just soiling or contamination but also chemical reactions. Sweeping out is also valuable on a physical level, since it generally improves the friction factor of the floor - dusty floors exhibit a lower coefficient of sliding friction.

Very smooth container floor

Absence or neutrality of odor is always required when odor-absorbing goods are stored or transported, otherwise their value could be adversely affected. Ensuring absence or neutrality of odor also means not using any odor-tainted or odor-emitting load securing equipment, dunnage or segregating materials in places where they could cause damage. Loads which can (could) negatively impact on each other must not be loaded together. Odor-neutrality is not required for the means of transport and accompanying load with most dangerous cargoes, but it can be important for certain chemicals. If odor-neutrality is required, appropriate information must be provided to the relevant offices. This is especially important if a molecular influence from other goods would have a damaging effect. In many cases, it is sufficient to remove residue from previous loads and to air thoroughly. Sometimes, it is useful to spray odor-binding chemicals, which should be environmentally friendly and in no way health-threatening or even toxic.

Special measures are required for storing, handling and transporting loads which are particularly odor-sensitive. The same applies if strong or badly smelling or dangerous loads have been shipped and the affected areas have to be prepared specially or restored before a load can be accepted. Extensive cleaning work, such as washing etc. can then be necessary. There are specialist companies on the transport market who offer these services.

Decontamination with special chemicals must be ordered specially and must be monitored. In certain cases, specialist companies with specially trained staff are to be called in.

Storage space and cargo transport units must be dry and offer protection from moisture, unless otherwise contractually agreed or this is not customary practice in a given trade. Generally, however, they must not show any defects which could lead to damage by moisture. Wet patches are to be removed by applying sawdust, dry sand or other absorbent materials and sweeping them up. Certain circumstances make it necessary to use special binders. In the simplest case, a thorough airing with "relatively" dry air is sufficient. To prevent moisture damage from occurring at a later date, the storage and stowage areas and means of transport must be inspected for leaks etc. This also means checking pipework, roofs, tarpaulins, doors, ventilation openings etc. and in particular checking the seals.

Moisture brought into a container by staff and forklifts

Danger of moisture being brought into a container

On rainy days such as this, no containers should be packed outside. It is another mark of good organization that either covered areas are provided or work is stopped under these conditions.

Long and short-term storage areas and cargo transport units must be free of any articles which could cause **mechanical damage**. They must therefore be inspected for materials which could damage the load, such as old load securing material, protruding mountings, incorrectly inserted roof bows or slats, sharp or pointed objects, etc. If there is a risk of damage, these items must be removed. This also includes removing old wires, wood splinters, nails, small stones etc. All protruding mountings, lashing rings, and sharp and pointed objects which cannot be removed, are to be covered. Carelessness during this work can not only cause significant damage to the goods themselves, but also consequential losses when the goods are further processed. An example of this is an instance of damage which occurred during the transport of newsprint in a container in which bags with plastic pellets had previously been transported. Due to inadequate cleaning, individual pellets became embedded in the paper rolls. When the rolls were subsequently processed, the granules brought a complete printing line to a standstill. The damage caused was enormous.

Inspections and protective measures are necessary before using cargo handling equipment, load-bearing equipment, mechanical aids, tools etc. They must not cause tears, pinching, pressure points, scratches, soiling or a reduction of quality or safety standards which depreciate the value of the goods. Defective equipment must be repaired so that it is suitable for use or be rejected. This includes checking the loading capacity of ground conveyors and lifting gear, load-bearing equipment, etc. The materials used must be adequate to meet the requirements for correct segregation and correct use of dunnage. They must be available in a sufficient quantity and be of an adequate quality. Any missing stock must be made up in good time, to prevent any delays. Unusable materials must be rejected. Load securing means and transport protection equipment which have been installed or supplied are to be inspected to ensure they are ready to use, complete and in perfect condition. This includes stanchions, trailer rails, roof bow mountings or slats, partitions, permanently installed lashing systems, airbags, etc.

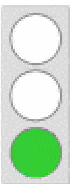
The **provision and selection of conventional load securing equipment** must be organized in good time. The most suitable materials are to be selected from those which are available or provided. Unusable parts must be rejected. Claims for incorrect or incomplete deliveries must be made in good time, to prevent time delays during purchasing or replacement delivery. Materials of this type could be: Steel wire, wire rope clamps, shackles, turnbuckles, steel strapping, lashing belts, lashing ropes, wood, etc. If individual items load securing equipment are passed on to third parties or used by third parties, this must be documented by appropriate receipts, etc.

Preparation of stowage, packing and storage areas or spaces must also include leveling any uneven surfaces. All surfaces, including container floors, must be prepared so as to enable work to be carried out without any delay. If goods are to be packed in several layers, it may be necessary to line, flatten or pad out the floor of the area with boards, planks, squared lumber etc. It must be possible to handle the goods by lifting gear or ground conveyors without difficulty.

The **load-carrying capacity and the permissible loading capacity of the underlying surface** must be checked. Permissible and required stacking loads, axle loads and wheel loads must be compared. Exceeding the permissible loading capacity or loads can result in damage to the operating equipment or cargo transport units. For some storage areas and CTUs, the permissible load or load-bearing capacity is clearly visible. It can sometimes be determined simply by dividing the load-bearing capacity or load limit by the loading area. The "General guidelines" of the UVV (a national German regulation) stipulate that permissible values must not be exceeded.

Necessary **protective clothing and equipment** must be requested and provided in good time. Basic safety clothing includes: Safety helmets, steel-capped safety boots with impervious soles and gloves. Gloves are indispensable for protection against "frayed edges" in wire ropes, splinters on rough wood, etc. When dealing with dangerous cargoes or working materials, it can be mandatory to use special protective clothing and equipment. Dust masks, filter masks or gas masks, acid-resistant footwear, antistatic footwear, rubber aprons, rubber boots, rubber gloves etc. must then be worn. It must be noted that even very traces of alcohol in the breath of the user can render certain filters ineffective. When using chainsaws, "saw-proof" clothing, ear protectors and face protection must be worn. Employers must provide the relevant safety equipment, employees must use it.

All necessary resources must be kept ready for **planning and documenting packing operations**. Computer lists, forms, marking pens and pencils, placards, rules, measuring tapes, etc. must be immediately accessible or available at all times, to prevent delays during handling.



An advantage:
Electronic support for packing with a forklift

Electronic support facilitates documentation and accelerates the handling process.

Supervisory authorities and specialists must be requested and informed in good time. These may be radiation protection experts, persons with appropriate qualifications for handling explosives or similar experts, who must be present during handling. Frequently, fire services, veterinary or plant protection officers, customs or similar authorities must also be brought in. In some cases, firefighting equipment must be to hand and the appropriate staff must be readily accessible. Provisions may need to be made for monitoring the handling process or the containers.

In some cases, it is required that extensive **information is provided to the staff**. When handling dangerous goods, all staff and other persons involved must be instructed before work begins about the special properties and risks associated with the load, and what protective measures need to be taken.

The names of all **supervisors** must be known to all persons involved in the monitoring process. A written record must be kept of the names of the appointed supervisors.

According to the CTU guidelines:

> *"responsible person" means a person appointed by a shore-side employer who is empowered to take all decisions relating to his/her specific task, having the necessary current knowledge and experience for that purpose, and who, where required, is suitably certificated or otherwise recognized by the regulatory authority.*

Hopefully he has not overlooked the fact that on one of the cartons, a label is only printed in black, and not permanently attached as a "colored label".

Responsible person?

It is essential that all safety instructions on the containers are observed. These instructions, for instance, stipulate that the refrigeration unit must be switched off, the doors must be opened wide and five minutes must elapse before entering the container:

Warning notice on a refrigerated container

To make **provision for emergencies**, staff should be informed about the location of fire alarms, emergency exits, the nearest stretcher and all relevant emergency numbers. In addition, every employee must be acquainted with the reporting procedures and general procedures in the event of faults and accidents occurring.

Trade association demands for safe workplaces must be met. These include adequately lit **traffic routes** and freely accessible **escape routes**. In Germany, for instance, one of the requirements is that:

The employer must ensure that only ramps which cover the entire width of the container are used when driving onto containers with ground conveyors.

Ramp

Inspection plate for the ramp

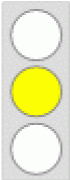
It is obvious that safety-relevant aids of this kind must be checked regularly.

Ramp

(2) *Drivers of ground conveyors must only drive onto containers and vehicles once all necessary ramps and bridging have been set up and secured against unintentional movement.*

Ramp secured against unintentional movement

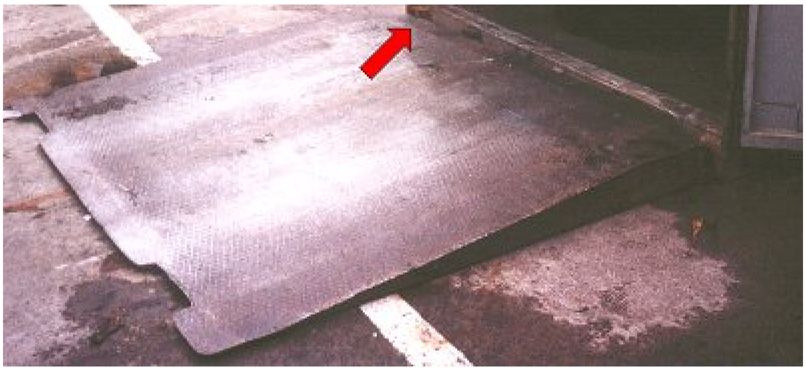
When driving onto containers, ramps are considered to be secured if they have been hooked into the containers or, for instance, lashed to the container with chains.



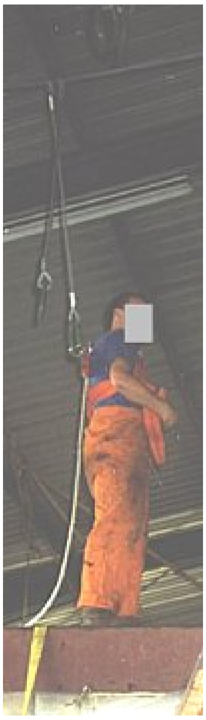
Not forbidden: Provisionally securing a ramp with chains

Even better: Securing a ramp with bolts

Unsecured ramp

Accident hazard caused by unsecured ramp

Workers must use equipment to **protect against falling** when working more than 2 m above the ground or above the height of a single container.

Employee protected against falling

4.2.1.1 Selecting and checking CTUs

From an economic perspective, the most suitable type of cargo transport unit is the one which best harmonizes the volume-to-payload ratio of the container with the stowage factor of the cargo. This provides the best utilization of the space and weight constraints. Other aspects that must be considered when selecting a CTU include: Type of product, weight, center of gravity, substructure and load-bearing surfaces, type of packaging, permissible loading capacity and/or stackability, load securing options, and other similar aspects. The internal dimensions, door dimensions and other similar information can be obtained from the owners of the CTUs or the relevant leasing companies or can be taken from their prospectuses beforehand.

In all cases, the CTU should be inspected. Not only for reasons of cargo care, but also for reasons of liability and accident prevention. "EIR"s are usually used at the handover points. This abbreviation stands for **E**quipment **I**nterchange **R**eceipt. They are receipts for the handover of containers, trailers, chassis and similar cargo transport units and items of equipment. On the basis of a visual inspection, the EIR lists, or marks in the diagrams printed on the form, all defects found on a CTU, for instance. If an inspection reveals, for instance, that a container exhibits damage which has not previously been documented, the costs for restoring or repairing it must be borne by the person who was previously responsible for the container. Thorough inspection and true and accurate documentation must therefore be in the interests of all parties involved.

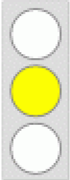
The CTU guidelines require a thorough inspection of the cargo transport units before they are packed. A number of issues are listed in the guidelines as a guide for visual inspection. For exterior inspection, the CTU guidelines prescribe the following:

> *2.1.1 The structural strength of a container depends to a great extent on the integrity of its main framework comprising the corner posts, corner fittings, main longitudinal and the top and bottom end transverse members which form the end frame. If there is evidence that the container is weakened, it should not be used.*

Fractures on a container

> *2.1.2 The walls, the floor and roof of a CTU should be in good condition, and not significantly distorted.*

These containers may not be packed.



Slightly deformed container side walls

This container can still be used. However, the distortion must be recorded in the EIR, the **E**quipment **I**nterchange **R**eceipt.

Doors in a technically sound state

2.1.3 The doors of a CTU should work properly and be capable of being securely locked and sealed in the closed position, and properly secured in the open position. Door gaskets and weather strips should be in good condition.

If containers are placed on an uneven surface, they become distorted. It is then only possible to open and close the doors with force. Fork-lift trucks are frequently misused in this way. "Dirty tricks" like this must be avoided. Unevenness of the ground or underlying surface must be leveled out before setting down the containers - possibly by using simple aids such as hardwood strips.

Top:
Plate as per UIC leaflet on a swap-body

Left:
CSC plate

2.1.4 A container on international voyages should be affixed with a current International Convention for Safe Containers (CSC) Safety Approval Plate. A swap-body may be required to have a yellow code plate, fixed at its side wall (for details see UIC leaflet 596), which proves that it has been codified in conformity with the safety rules of European railways. Such swap-bodies need not be affixed with a CSC plate, but many of them will have one in addition to the yellow code plate.

Traces of removed placards

2.1.5 Irrelevant labels, placards, marks or signs should be removed or masked.

Placards which have not been completely removed can lead to mistakes! Are they still valid after all?

Lashing point on a semi-trailer

2.1.6 A vehicle should be provided with lashing points for securing it aboard ships (refer to ISO 9367-1: "Lashing and securing arrangements on road vehicles for sea transportation on Ro/Ro ships - General requirements - Part 1: Commercial vehicles and combinations of vehicles, semi-trailers excluded" and to ISO 9367-2: Lashing and securing arrangements on road vehicles for sea transportation on Ro/Ro ships - General requirements - Part 2: Semi-trailers".)

Canvas covers

2.1.7 When canvas covers are used, they should be checked as being in satisfactory condition and capable of being secured. Loops or eyes in such canvas which take the fastening ropes, as well as the ropes themselves, must be in good condition.

Loading a swap-body

2.1.8 When loading swap-bodies, it should be borne in mind that in most cases, the bottom and floor of swap-bodies are the main areas of their structural strength.

Checking vehicles includes checking the loading area, the side walls, the locking equipment, the support legs, the load securing devices, the supports used to guide the cover, the slats used to guide the cover, the canvas covers and the section where canvas cover is closed.

When performing an interior inspection, the CTU guidelines stipulate the following:

Scrape marks on the roof of an O.T.

Has this already rusted through?

2.2.1 A CTU should be weatherproof unless it is so constructed that this is obviously not feasible. Previous patches or repairs should be carefully checked for possible leakage. Potential points of leakage may be detected by observing if any light enters a closed unit. In carrying out this check, care should be taken to ensure that no person becomes locked inside a unit.

There was one case in which employees locked a colleague inside a container during a check before a work break as a practical joke. During the break, the container was then removed. The employee, who suffered from claustrophobia, then had a heart attack. Practical jokes of this kind must be severely sanctioned by the company.

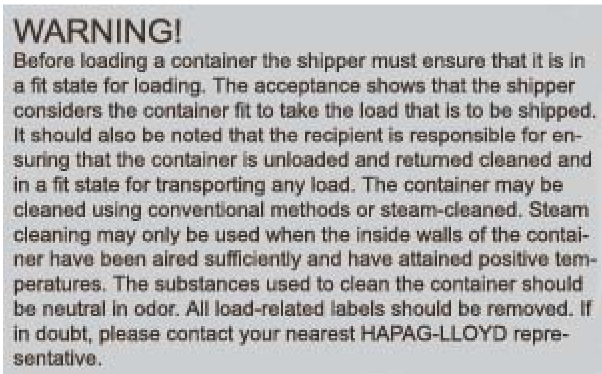
Crack in a container

Hole in a plywood container

2.2.2 A CTU should be free from major damage, with no broken flooring or protrusions such as nails, bolts, special fittings, etc. which could cause injury to persons or damage to the cargo.

Lashing eye on a flatrack

2.2.3 Cargo tie-down cleats or rings, where provided, should be in good condition and well anchored. If heavy items of cargo are to be secured in a CTU, the forwarder or shipping agent should be contacted for information about the cleat strength and appropriate action taken.



WARNING!
Before loading a container the shipper must ensure that it is in a fit state for loading. The acceptance shows that the shipper considers the container fit to take the load that is to be shipped. It should also be noted that the recipient is responsible for ensuring that the container is unloaded and returned cleaned and in a fit state for transporting any load. The container may be cleaned using conventional methods or steam-cleaned. Steam cleaning may only be used when the inside walls of the container have been aired sufficiently and have attained positive temperatures. The substances used to clean the container should be neutral in odor. All load-related labels should be removed. If in doubt, please contact your nearest HAPAG-LLOYD representative.

Notice regarding the fitness for loading of a container

2.2.4 A CTU should be clean, dry and free of residue and persistent odors from previous cargo.

This point in the CTU guidelines relates to the fitness for loading of cargo transport units. For further information on this subject, see the section on "Preparatory work".

2.2.5 A folding CTU with movable or removable main components should be correctly assembled. Care should be taken to ensure that removable parts not in use are packed and secured inside the unit.

This is particularly important for flatracks. Notices describing how to set up and fold these CTUs safely are generally attached to these containers. For further information, see the section "Other markings".

4.2.1.2 Before packing

Section 3.1 of the CTU guidelines deals with actions required before packing. The following are some of the points defined in the guidelines:

> *3.1.1 Before packing a CTU, careful consideration should be given as to how the unit will be presented during the packing operation. The same applies for unpacking. The CTU may be presented for packing or unpacking as follows:*
>
> - *loaded on a semi-trailer chassis together with a truck;*
> - *loaded on a semi-trailer chassis, but without a truck;*
> - *loaded on a rigid truck or chassis;*
> - *standing on the ground;*
> - *standing on its supporting legs (in case of class C swap-bodies);*
> - *loaded on a rail-car;*
> - *loaded on an inland barge; or*
> - *loaded on a seagoing vessel.*
>
> *Any of these configurations is possible. The actual packing or unpacking situation often depends on site and facility considerations. However, whenever the CTU is presented on a chassis or on supporting legs, special care should be taken in planning the packing or unpacking operation.*
>
> *3.1.2 A CTU to be packed should rest on level and firm ground or on a trailer or a rail-car. If a CTU is on a trailer, care should be taken to ensure the trailer cannot tip while the container is being packed, especially if a lift truck is being used. If necessary, the trailer should be propped. Brakes should be securely applied and the wheels chocked.*

The CTU guidelines highlight particular hazards with illustrations and relevant comments.

40' high cube container loaded on a chassis

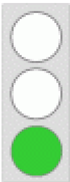
The support legs of the chassis are designed in such a way that they can carry the total permissible weight of the load or their own maximum payload. However, the support legs are unable to bear additional forces which would arise e.g. by driving into a container of this kind with a fork-lift truck.

Risk of accident: Inadequate support

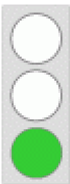
The CTU guidelines also provide a warning regarding inadequate support of semi-trailers.

Dangerously inadequate support of a chassis

There is a very great risk of the pallet collapsing at the slightest horizontal movement of the semi-trailer. During loading and unloading, the position of the loading area in relation to the horizontal plane changes, because the vehicle rides up and down on the suspension.



Correctly supported chassis

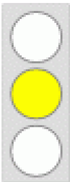


Correctly supported chassis - detail

Thanks to the wheels and the handles, the support can be moved without a vast amount of effort. The wheels are effectively deactivated when the support is loaded against the spring and reactivated when the load is relieved.

Adjustable-height support - detail view

Approved supports are inspected and bear an appropriate approval plate with the necessary data on their permissible loading capacity.



This is a genuine picture

For reasons already given, the height of the chassis changes with the container during handling. The supports must therefore be regularly checked and adjusted. Any continuation of work under these conditions would represent a breach of regulations.

A swap-body standing on its support legs

3.1.3 When a swap-body standing on its supporting legs is packed, particular care should be taken to ensure that the swap-body does not tip when a lift truck is used for packing. It should be checked that the supporting legs of the swap-body rest firmly on the ground and cannot shift, slump or move when forces are exerted on the swap-body during packing.

A swap-body can be shored provisionally by stacking hardwood pallets with a sufficient loading capacity horizontally on top of each other or by using cross-beams made of squared lumber of a sufficiently large cross-section. These aids would also have to be checked regularly and their height adjusted. As this is only possible in practice if work is interrupted, such provisional solutions are not recommended. As a precautionary measure, swap-bodies should be provided with additional support if fork-lift trucks are to be driven into them. The CTU guidelines only advise that fork-lift trucks do not drive onto the swap-bodies too quickly. The picture below illustrates the danger of the legs bending. It is better to never drive onto a swap-body with fork-lift trucks - or even to move loads horizontally in other ways with heavy equipment, if the containers are only standing on their legs - but unfortunately this is common practice.

Potentially lethal negligence

Before driving onto a swap-body, it should always be checked that the supports are sound and are securely fastened. Here, not only is one "leg" deformed, but the diagonal support is even fastened with "ropes"!

The relevant German trade association also demands:

> *The employer may only use ground conveyors for driving onto containers and vehicles if no dangerous concentrations of health-threatening exhaust gas substances can be produced in the inhaled air.*

Devices for reducing the quantity of dangerous substances in exhaust gas include, for instance, exhaust purification systems with catalytic converters. For guidelines on the use of vehicles driven by Diesel engines, see the German Technische Regeln für Gefahrstoffe TRGS 554 "Dieselmotoremissionen" (Technical Regulations for Hazardous Substances "Diesel engine emissions").

For information on securing the vehicle to be loaded or unloaded against unintentional movement, see Section 37 Para 2 of the German Accident Prevention Guidelines (UVV) for vehicles.

4.2.1.3 Stowage planning

Working and general stowage plans are prepared and used in normal maritime transport. The same practice should be adopted when packing other cargo transport units.

The CTU guidelines even make this an obligation: Section 3.1 of the CTU guidelines deals with actions required before packing. The following are some of the points defined in the guidelines:

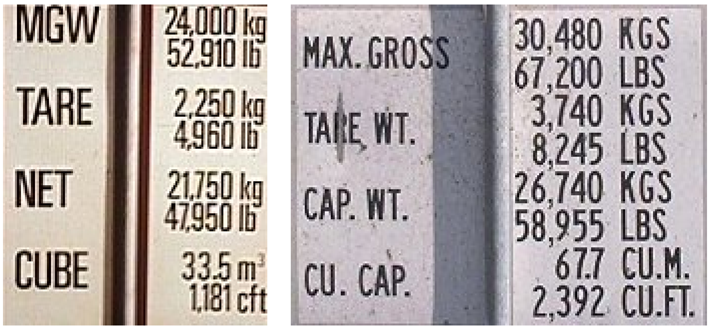
> *3.1.4 Packing should be planned before it is started. This should make it possible to segregate incompatible cargoes and produce either a tight or secured stow, in which the compatibility of all items of cargo and the nature, i.e. type and strength, of any packages or packaging involved are taken into account. The possibility of cross-contamination by odor or dust, as well as physical or chemical compatibility, should be considered.*

This point gives some fundamental guidelines as to basic stowage methods. Corresponding explanations and illustrations are provided in section 4.2.4 in this Container Handbook.

Not packed tightly and securely!

Packed tightly and securely

> *3.1.5 The planned cargo should not weigh more than the maximum payload of the CTU. In the case of containers, this ensures that the permitted maximum gross weight of the container (which includes the payload) marked on the CSC Safety Approval Plate will never be exceeded (see also Annex 3). For CTUs not marked with their maximum permissible gross weight, tare weight or any other features, any of these values should be known before packing starts. According to CEN standards, a swap-body of class C (7.15 m to 7.82 m) will have a maximum gross mass of 16,000 kg and a swap-body of class A (12.0 m to 13.6 m) will have a gross mass of up to 32,000 kg.*



Information on a 20' and a 40' container

Annex 3, which is referred to under this point, deals with the consequences of overloading CTUs. Precise planning of packing is indispensable. Planning becomes even more important when the amount of the load to be packed is sufficiently large, in that it ensures that the containers are utilized to their maximum in terms of space and weight. This is the only way to minimize transport costs. A detailed packing plan is indispensable for this.

The volume-to-payload ratio of the containers can be determined from their volume and payload information, which can be obtained beforehand from prospectuses or documents provided by the container owners. The volume-to-payload ratios for the containers shown are calculated as follows:

20' container = 33.5 m^3 / 21.75 t = 1.54 m^3/t

40' container = 67.7 m^3 / 26.74 t = 2.53 m^3/t

This means that for every metric ton of payload on the 20' container, 1.54 m^3 of packing space is available, and

on the 40' container there is 2.53 m³ available per metric ton of cargo mass. The volume-to-payload ratio of a transport container therefore answers the question "How many cubic meters of stowage volume are available per metric ton of payload?"

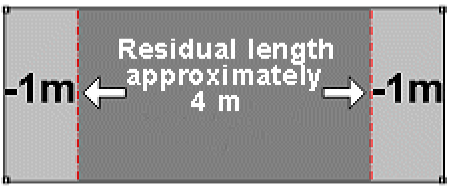
The dimensions and masses of the items to be loaded can be used to determine the stowage factor of the load. Assuming that a consignment of 200 metric tons is to be loaded: The volume of the items is calculated to be 440 m³. The net stowage factor of the cargo is calculated by dividing the cargo volume by the cargo mass. Net stowage factor of the cargo = 440 m³ / 200 t = 2.2 m³/t. This means that, if the load is packed with no wasted space, a volume of 2.2 m³ would be required for every metric ton of cargo. Since most loads are not 100% suitable for modular packing, certain losses will result from stowage or packing. Experienced practitioners can estimate these losses well or know from their own records what values are to be taken for calculation purposes. This information can also be obtained from relevant specialist literature. For our example, let us assume stowage loss of 10 %. The gross stowage factor will then not be 2.2 m³/t but in fact 2.42 m³/t. Experts also say: "Cargo is stowed by a factor of 2.42". A comparison with the volume-to-payload ratios of the containers immediately reveals that economical transport can only be expected with the 40' containers.

If a consignment of 300 m³ volume and 230 t mass were waiting for loading and it were known that 15% stowage loss is to be expected, the net stowage factor of the cargo would be 300 m³/ 230 t = 1.30 m³/t and the gross stowage factor 1.5 m³/t. In this case, experts would say: "Cargo is stowed by one and a half times" or: "Cargo is stowed by a factor of 1.5". By comparing the numeric values, it can immediately be seen that only 20' containers can be considered for economical transportation.

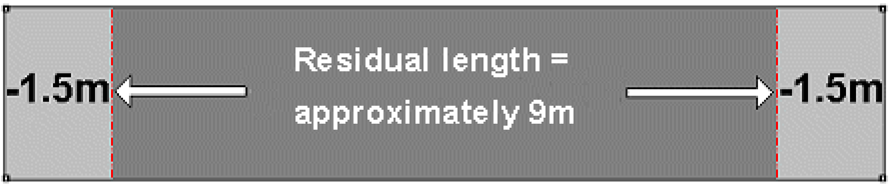
Other aspects must of course still be considered, such as factors relevant to a particular transport route or to the destination countries, etc. These points are dealt with in the following and other sections of this Handbook. Notes can also be found in the CTU guidelines:

> *3.1.6 Notwithstanding the foregoing, any height or weight limitation along the projected route that may be dictated by regulations or other circumstances (such as lifting gear, handling equipment, clearances and surface conditions) should be complied with. Such weight limits may be considerably less than the permitted gross weight already referred to.*
>
> *3.1.7 Stowage planning should take account of the fact that CTUs are generally designed and handled assuming the cargo to be evenly distributed over the entire floor area. Where substantial deviations from uniform packing occur, special advice for preferred packing should be sought.*

This applies indirectly to the line load of containers. This is determined by dividing the payload of the containers by a calculation length. For 20' containers, this calculation length is 2 m less than the container length, for 40' containers 3 m less. It can also be expressed as follows: In order to obtain the calculation length, 1 m is subtracted from each end for 20' containers and 1.5 m from each end for 40' containers.

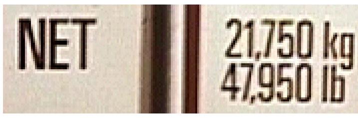


Determining the calculation length for the line load for 20' containers



Determining the calculation length for the line load for 40' containers

The payload, maximum gross weight (MGW), net, capacity weight (CAP WT) or whatever is specified on the container as the permissible payload, is divided by the relevant calculation length. The result is the permissible line load.



divided by

4 m | **9 m**

equals

for the 20' container | for the 40' container

a permissible line load of:

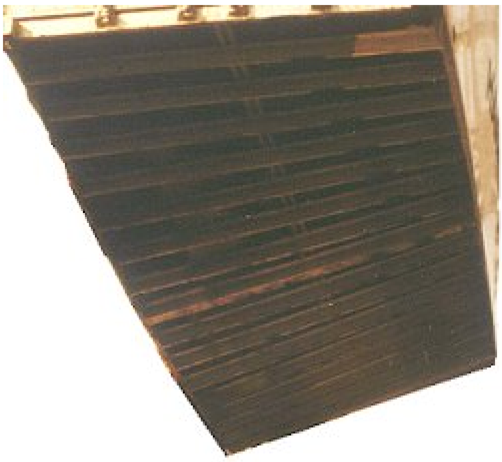
5,437.5 kg/m | **2,971.1 kg/m**

It must be noted that the payload should actually be given in Newtons and the line load in Newtons per meter or daN/m or kN/m, if the line load is assumed to be a force. If the line load is regarded as a "line mass", the units kilogram per meter or metric tons per meter would be completely correct.

For older 20' containers with a payload of around 18,000 kg, the permissible line load is this around 4.5 t/m, while for older 40' containers with an average payload of 27,000 kg it is -3.0 t/m. On more modern containers, the values are considerably higher: On some 20’ containers, as much as 6.75 t/m. If necessary, the current values must be determined for every loading operation.

3.1.8 When a heavy, indivisible load is to be shipped in a CTU, due regard should be given to the localized weight-bearing capability of the unit. If necessary, the weight should be spread over a larger area than the actual bearing surface of the load, for example by use of properly secured baulks of timber. In such a case the method of securing the load should be planned before packing is started and any necessary preparations should be made.

For instance, a machine part weighing 20 t and 3 m long could not simply be loaded into the 20' container described above without additional measures being taken. There would be a danger of it damaging the container floor.

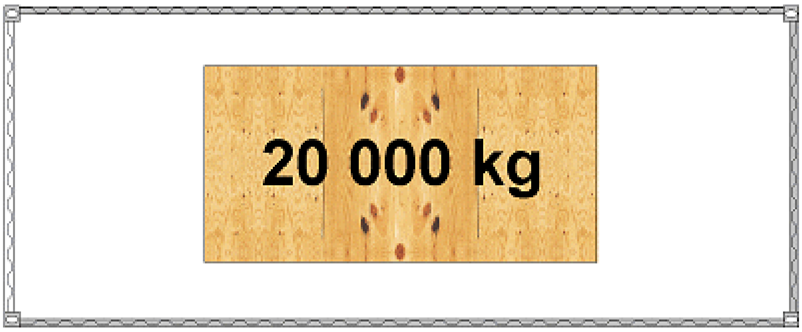


Container floor seriously deformed due to overloading

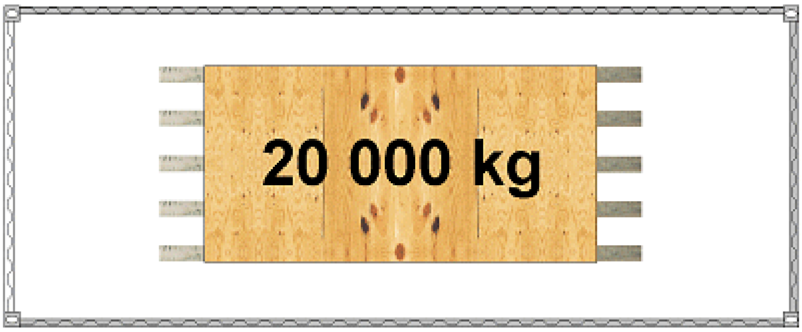
The machine part used as an example (20 t weight, 3 m long), exerts a load of 6.666 metric tons per running meter. This is calculated by dividing 20 t by 3 m. Since forces are involved, a correct calculation would have meant dividing the normal force of 19,620 N by the length of 3 m. This would have produced the correct values of 65,400 N/running meter, 6,540 daN/running meter or 65.4 kN/running meter. Comparison with the permissible line load of the container of 5,437.5 kg/m (5,334.2 daN/m or 53.342 kN/m) immediately reveals that loading cannot be carried out unless additional measures are taken.

Bottom cross members of a container deformed due to overloading

In this example, this means that the weight of the case has to be distributed over a larger number of bottom cross members. This can be achieved by laying squared lumber longitudinally across them. The required length of the squared lumber is determined by dividing the weight of the case (or more correctly the "normal force") by the permissible line load of the container. In the example, this would be 20,000 kg divided by 5,437.5 kg/m = 3.68 m (19,620 daN / 5,334.1875 daN/m = 3.68 m).

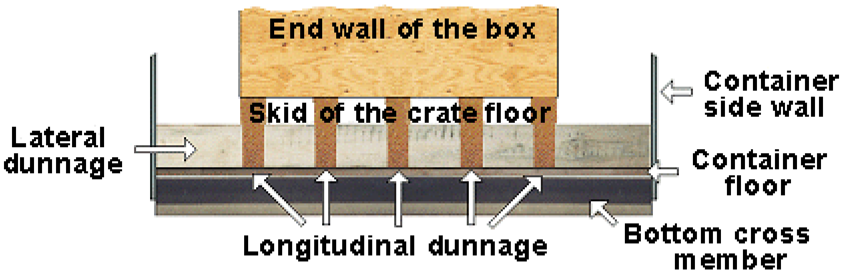


Non-permissible loading of 20 t machine box: Line load too great



Permissible loading with appropriate line load

An older model of container would not have been permitted to be used for transport, due to its low permissible payload of 18,000 kg. A more modern model of container with a payload of 24,000 kg has a line load of 6 t/m. The box could be loaded into a container of this kind without requiring any further measures. If the box is to be loaded with very very light but bulky items in the 40' container in the example, the following calculation would need to be made: 20,000 kg / 2,971.1 kg/m = 6.73 m. In the 40' container described, the box would have to be placed on squared lumber which was at least 6.73 m long. As far as practical considerations are concerned, it should be noted that where possible squared lumber with a large vertical edge length should be used, e.g. 8 cm x 16 cm or 10 cm x 20 cm etc. Half-sizes of this kind are generally less expensive. However, since there is a danger of them collapsing, they must be braced firmly laterally to prevent tilting. Preferably, this should result in a wooden lattice with a large height.



3.1.9 *If the planned cargo of an "open topped" or "open sided" CTU will project beyond the overall dimensions of the unit, special arrangements should be made. It should be borne in mind that road traffic regulations may not allow such overhangs. Furthermore, CTUs are often loaded door-to-door and side by side, thus not permitting any overhang.*

Photographic representation: Flatrack with overhang on both sides in the cellguides of a ship

It can clearly be seen from this photographic representation that three slot rates must be paid for transport, since the two adjacent slots on the ship must be kept free.

Photographic representation: Flatrack with overhang on one side in the cellguides of a ship

If the center of gravity of the flatrack makes it technically possible to load it with an overhang on one side and it is also possible to load it in this state on the ship - after agreeing this with the shipping company - , only two slot rates will have to be paid.

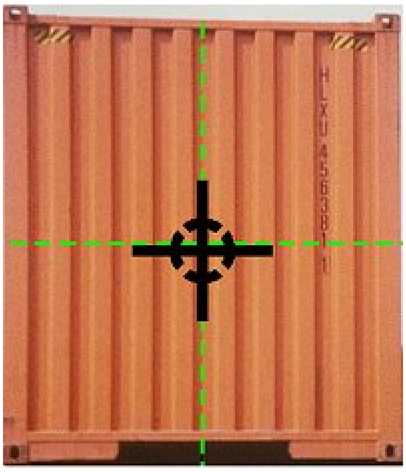
Marking for overwidth loads for road transport

Overwidth road vehicles must be marked with red and white, diagonally striped plates.

On board the ship, overheight flatracks can only be stowed as the uppermost container either in the hold or on deck. Ships with flaps can segregate individual stowage areas from others and could also store the flatrack in another position. As one slot must be kept free above the flatrack, two slot rates must also always be paid.

Overheight flatrack

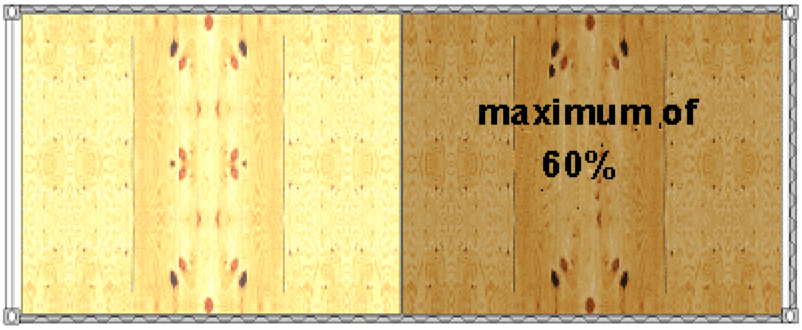
3.1.10 The center of gravity of the packed cargo should be at or near the longitudinal center-line of the CTU and below half the height of the cargo space of the unit. (see also 3.2.5 and other relevant sections.)



Prescribed center of gravity for loaded containers

3.2.5 The weight of the cargo should be evenly distributed over the floor of a container. Where cargo items of a varying weight are to be packed into a container or where a container will not be full (either because of insufficient cargo or because the maximum weight allowed will be reached before the container is full), the stow should be so arranged and secured that the approximate center of gravity of the cargo is close to the mid-length of the container. If it is not, then special handling of the container may be necessary. In no case should more than 60 % of the load be concentrated in less than half of the length of a container measured from one end. For vehicles, special attention should be paid to axle loads.

Ideal load distribution in a container with a payload of 18,000 kg



Maximum permissible weight shift for containers

If necessary, the real center of gravity of the container must be determined by calculating its moment.

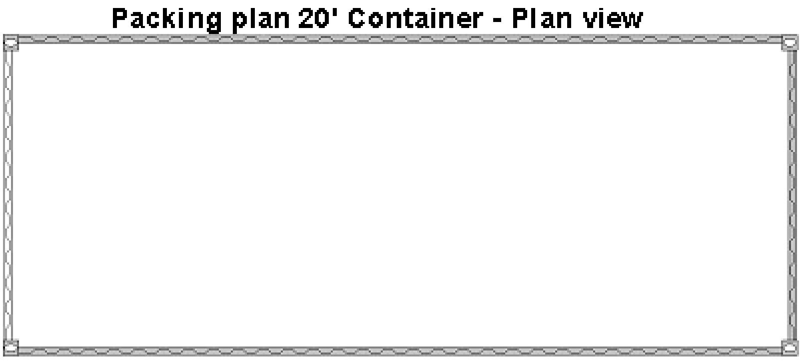
3.1.11 When planning the packing of a CTU, consideration should be given to potential problems which may be created for those who unpack it, e.g. cargo falling when doors are opened.

Danger to persons due to badly packed containers

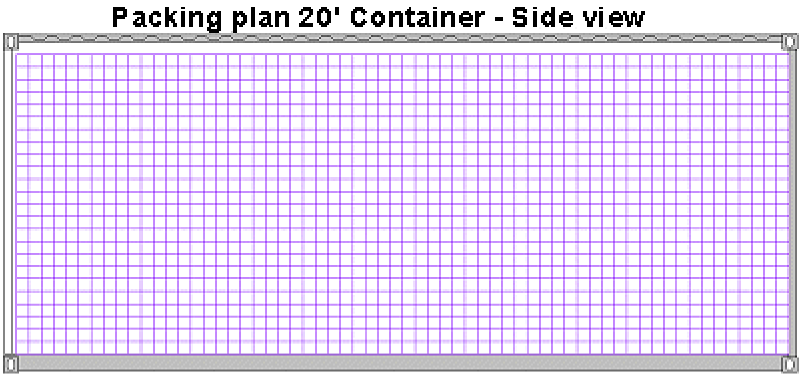
This cartoon figure appear amusing, but in the real world, dreadful incidents have occurred. To cite only one accident here: Cotton bales weighing around 220 kg falling out onto a worker injured him so severely that he suffered serious fractures to his spine and hip in addition to internal injuries to vital organs. The young man only survived thanks to immediate medical attention and a number of operations. For the rest of his life, he is now confined to a wheelchair. And all this simply because the cotton bales in the container were badly packed and not secured.

3.1.12 Before a CTU is packed, it should be ensured that the personnel responsible for the packing are fully informed about all the risks and dangers involved. As a minimum requirement some sketches showing the basic rules of CTU packing should be available. The present Guidelines should also be readily available. If necessary, the shipper and the packing personnel should consult each other regarding any special feature of the cargo to be packed into the units. In particular, information on possible dangerous cargoes should be considered very carefully. Consideration should also be given to the provision of appropriate training for personnel involved in packing CTUs.

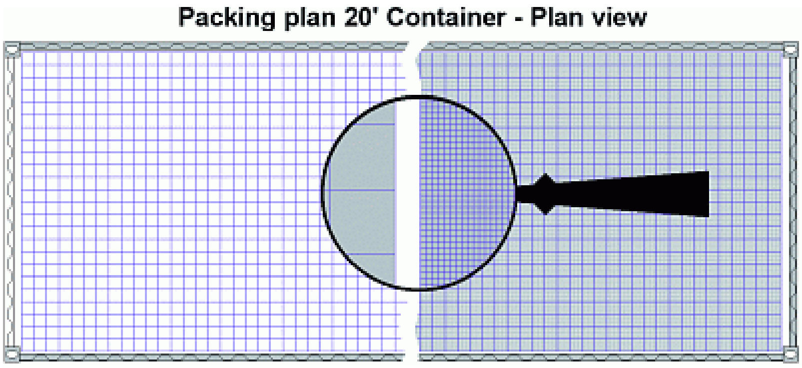
Data sheets with a plan view and/or side view of different containers, in which the items to be packed are drawn in to scale, should be provided for planning packing.



Blank form for a packing plan



Blank form for a packing plan with dm² grid



Blank form for a packing plan with dm² or cm² grid

The actual design of the packing plans is of little significance. What is crucial is that they contain all the most important information, e.g. the interior dimensions of the container, and that the stowage plan can also provide important evidence in the event of any subsequent (legal) disputes.

When planning packing and illustrating it in the forms, the following points must be considered: How are an even load along the floor and an acceptable center of gravity to be achieved? What goods will have to be brought in using a fork-lift truck? Will any other ground conveyors need to be used? Is manual handling necessary - or even desired? Do all items have a sufficient loading capacity? Can they be stacked? Will items have to be packed on top? Can the necessary basic stowage rules be met for all items? Are dangerous cargoes also to be loaded? Has unloading also been considered? And so on.

It should be checked whether the stowage factor of the cargo has previously been determined using the weights and dimensions of the cargo and compared with the volume-to-payload ratio of the container. This is always good practice; moreover, this procedure gives all less experienced staff an insight into what is feasible. It goes without saying that the maximum payload of the container must not be exceeded.

3.1.13 *When packing a CTU, the shipper and persons responsible for packing should bear in mind that any failure to pack and secure the cargo correctly may result in additional costs that they will have to bear. If, for example in railway transport, a unit is found not to be properly packed and secured, the rail-car may be marshalled out of the train into a siding and the transport can only be continued once the cargo has been properly secured. The shipper may have to pay for this work, especially for the repacking and resecuring operation, as well as for the additional time during which the rail-car has been used. In addition, he may be held responsible for any delay of the transport operation.*

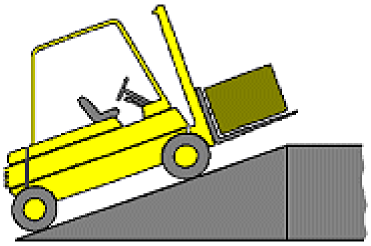
3.1.14 *Not all handling equipment is suitable for container packing. Lift trucks used for container packing and unpacking should have a short lifting mast and a low driver's overhead guard. If the lift truck operates inside the container, equipment with electric power supply should be used. Container floors are built to withstand a maximum wheel pressure corresponding to an axle load of a lift truck of 5,480 kg or 2,730 kg per wheel. Such an axle load is usually found on lift trucks with a lifting capacity of 2.5 t.*

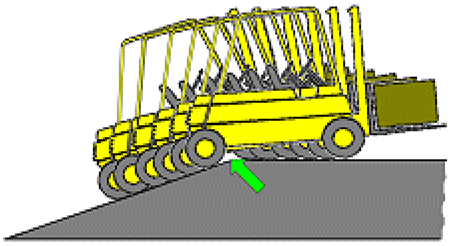
The short lifting mast and low driver's overhead guard alone do not say anything about the usefulness of the fork-lift truck. If these values are less than the height of the door, the fork-lift truck container can de driven into the container, but it is not automatically clear whether load can be stacked. This is where free lift is crucial. The higher the forks can be lifted without changing the total height, the more suited the fork-lift truck is for stacking and working in the container.

More information is provided on axle loads and working with fork-lift trucks in other sections of this Handbook.

Fork-lift truck with a large free lift for loading box containers

3.1.15 *If the CTU floor is at a different height level than the loading ramp, a bridging unit may need to be used. This may result in sharp bends between the loading ramp and the bridging unit as well as between the bridging unit and the CTU floor. In such cases the lift truck used should have sufficient ground clearance to ensure that the chassis does not touch the ramp when passing these bends.*





Sufficient ground clearance for a fork-lift truck

4.2.2 Using segregating materials

The term "segregation" is used to describe the visible segregation of packages or batches of cargo.

It can be useful to segregate loads in a transport container which are of the same type type but destined for different recipients if the goods could otherwise be confused or subsequent sorting work might be required. Sorting involves considerable time outlay which can lead to additional costs. Segregating goods in good time is therefore critical for cost-effective delivery of goods to their final destination or to interim destinations.

It is thus of great economic significance for conventional maritime transport and for storage. Segregation plays a less important role in the transport of cargo with containers and other cargo transport units.

Segregation is unnecessary if there is no danger of goods being confused because they have different package dimensions, a different shape or color or other different characteristics.

Transport law stipulations require that the consignor, carrier or shipper of a cargo provide the goods for delivery in a suitable condition, meaning that the goods must be both complete and in an undamaged condition. Such legislation may lead to an obligation to segregate the goods.

In principle, two different methods are used for segregation:

- spatial segregation and
- optical segregation using appropriate materials.

Spatial segregation of batches of cargo or individual packages is relatively easy to carry out on shore. On open spaces, and in sheds or warehouses, the storage spaces are indicated by appropriate location specifications, chalk marking or similar markings. For domestic transport, spatial segregation is achieved by delivering the different batches in separate vehicles or freight cars or by packing them separately in such vehicles or cars. Virtually the same principle applies for container cargoes.

The following requirements must be met when segregating cargo batches of the same kind or with the same appearance using segregation materials:

- The materials used must not cause any damage to the goods or their packaging, either by depreciation of their sales value or as a result of loss or shrinkage;
- Marking of the goods must not be rendered illegible by segregation;
- Segregation must be clearly recognizable.

With the exception of talcum, all materials described in the section "Dunnage" (see section 4.2.3) are used as segregation materials, e.g. wooden boards, wooden panels and walking boards, squared lumber, planks, boards and wooden dunnage, sailcloth, canvas and tarpaulins, reed, rattan or bamboo mats, films, cardboard and paper etc. The properties of these materials and their benefits and disadvantages are also described in the section "Dunnage" and will therefore not be discussed further here.

Materials which are only used for segregation are:

- Thin synthetic plastic nets or cargo nets
- Ropes, cloth strips or jute fabric strips
- Paints, marking pens, etc.

Thin synthetic plastic nets are relatively inexpensive. Segregation with these nets is easily recognized and does not cause any loss of stowage space. In addition, they are easy to transport and store, clean and reuse. Another benefit is that they do not hinder any necessary ventilation measures. A disadvantage is that they pose a hazard if anyone becomes entangled in them. To a certain extent, they are a trip hazard. They cannot be used to segregate bulk cargo.

Much the same applies to **cargo nets** as to thin nets. They are also expensive, more bulky and very difficult to free from odor infection. Under certain circumstances, they can cause pressure marks on the cargo.

Ropes are suitable for segregating long cargo items, such as structural welded steel mesh, roundwood and cut lumber, TOR steel etc., provided there is no risk of pressure marks. Fiber ropes are preferable to wire ropes, since the latter can cause rust damage. Impregnated ropes could cause a cargo to be infected by odors.

Strips made of various materials or **adhesive strips** are preferable to ropes, as they do not cause pressure marks and lead to smaller cavities and spaces. They are also generally cheaper. Cloth strips or jute fabric strips should never be used for fatty organic cargoes, as they could encourage or cause the cargo to ignite spontaneously.

Marking pens and paints can be used to indicate packages which belong together or the same batches, by means of clear signatures, color codes or stripes. They are only suitable for segregating goods if they do not restrict the further processing and actual marking of these, and if value of the goods does not depreciate as a result of any segregation indications. For instance, descaled metal sheets must not be marked with wax crayon, as otherwise it will subsequently be impossible to coat them without additional work. In the case of soft or absorbent woods, partial or total damage could be caused by using e.g. water-based paints.

Sufficiently heavy-duty and dense materials should be used to segregate bulk goods. Otherwise, parts of the various batches could become mixed if the segregation materials were to tear or develop leaks. Covers made of sailcloth, tarpaulin, canvas or strong plastic sheeting are suitable. The materials used to segregate grains and foodstuffs must be non-toxic and neutral in odor.

4.2.3 Dunnage

Dunnage materials or, more simply, dunnage, is the name used for all materials which are not firmly attached to the cargo transport unit, the cargo or its packaging, and are used to protect the load. This includes: Wooden dunnage, beams, planks, boards, wedges, plywood and hardboards, walking boards, mats, paper, sailcloth, canvas and tarpaulins; plastic and metal sheets, spray covers; cardboard and paperboard, packing paper, oiled paper and fabric paper, talcum powder etc.

Whether a material is to be classed as dunnage, segregation or load securing material does not depend on the material itself but on its application.

The main functions of dunnage are:

- Protection against sweat and condensation water
- Protection against moisture and liquids
- Protection against soiling and contamination
- Protection against mechanical damage

Sweat water can occur as container sweat or cargo sweat. It is primarily the roof surfaces that are susceptible to container sweat with the sides and the floor of the container only being a secondary source of problems. Top dunnage and side dunnage can absorb sweat dripping from the container roof until they reach saturation point. This can sometimes significantly delay, or even completely prevent, moisture damage. Dunnage cannot protect against cargo sweat, although this is rarer when goods are transported in containers.

To ensure **protection against moisture and liquids**, cargoes which are at risk and sensitive parts of the means of transport must be shielded. A check must be made for any possible leakage in the means of transport or other cargo items. Potential causes of this could be leaky walls, doors and roofs on the cargo transport units, or damaged drums, cans and other similar packaging receptacles for "wet cargoes". The effects of wet or very moist load securing materials must also be taken into account.

Protection against soiling and contamination must be ensured. This can be caused by the presence of contaminating goods or contaminated components on the cargo transport units. Contaminating goods must also be enclosed by dunnage to prevent them from damaging other goods or parts of the means of transport.

Preventive measures are always needed to **protect against mechanical damage**, if contact with components on the cargo transport unit itself or other loads or load items could cause mechanical damage. For instance, it can be necessary to adequately protect the load against contact with corrugations, corner posts, doors, lashing points, stanchions, edges and corners of other cargo items, load securing materials, protruding nails, screws etc. Appropriate dunnage must also be used to reduce the effects of harmful pressure forces.

The **nature of the materials used** must ensure that the packages or the cargo transport unit are adequately protected. The materials themselves must not be wet, moist, odor-tainted or contaminated. The quality of the material must determined for each individual case by assessing the value and susceptibility to damage of the load, the means of transport, the intended protection and other similar factors. The special properties of the particular type of dunnage used must be taken into account.

Wooden dunnage made of squared lumber, planks, boards, slats and battens, are very suitable for distributing pressure, bridging or lining cavities and gaps, creating air channels and enhancing friction. If wooden dunnage is laid too tightly, it impedes air circulation (this is a particular consideration for ventilated containers), causes a significant loss of stowage space and thus increases costs. Large spaces promote air circulation but can cause mechanical damage to the packages if the load-bearing area is too small. Wood easily absorbs moisture and releases it into the environment at a low vapor pressure. If it has a strong intrinsic odor or has taken up a foreign odor, it must not be used with odor-sensitive loads. Since wood can be infested by pests, only wood which has been impregnated against insects or fumigated may be used on certain trade routes. To distinguish such treated wood from normal wood, it must be appropriately stained or marked in some other way.

Wooden boards, wooden panels, walking boards, chipboard and hardboards are very suitable for distributing pressure and have a high loading capacity provided they are sufficiently thick. Since water-repellent, pest-proof or fire-retarding wood is odor-tainted as a result of such treatment or could have other harmful effects, it must virtually never be used with foodstuffs or similar items.

Mats made of rattan, bamboo, reed etc. only protect against surface dirt, not against dust. They absorb moisture and under certain circumstances release it back into the atmosphere. This can protect adjacent loads. Mats are easy to put in place and roll back up again, and do not cause any significant loss of stowage space. Provided a container is actively ventilated, mats can release back into the atmosphere any sweat or drops of water they have absorbed.

Canvas has a water-repellent impregnation and therefore not suitable for odor-sensitive goods. They are dust-tight. They impede air circulation.

Tarpaulins are watertight, dust-tight and airtight and very expensive. They must be handled with care if a long life is to be expected. It is very rare that tarpaulins will not be needed as a cover to protect against moisture and similar

influences.

Jute coverings protect against surface dirt but not dust. They are breathable and allow a minimal amount of ventilation. They pass on absorbed moisture to the wrapped or surrounding cargo items. When used with fatty organic goods, jute coverings can spontaneously ignite or promote the spontaneous combustion of other goods.

Sailcloth has similar properties to canvas.

Plastic sheeting is available in a number of different thicknesses. It is neutral in odor, inexpensive and generally acid-proof and alkali-proof. It is watertight, dust-tight and airtight but only impervious to water vapor to a limited degree. It has a low loading capacity if it is not sufficiently thick. Composite sheeting is often very heavy-duty but comparatively expensive.

Paper, e.g. normal kraft paper, is inexpensive and dust-tight, but very sensitive to moisture. Fabric paper has a higher strength. Oiled paper is watertight. Tissue paper is acid-free.

Dispersible material such as talcum powder and similar materials can be used to prevent cargoes from caking together.

Depending on their **use and application**, a distinction is made between:

- Floor dunnage
- Interlayer dunnage
- Top dunnage
- Side dunnage

Floor dunnage is used for the following tasks:

- Dissipating and localizing sweat and moisture
- Protecting the load from moisture and dampness on moist or wet stowage surfaces or stowage spaces
- Dissipating or restraining moisture leaking out of the load, to protect other packages or the cargo transport unit
- Protecting the load from soiling, contamination or mechanical damage from the stowage surface or stowage spaces
- Protecting the cargo transport unit against negative influences from the goods

There are no generally binding regulations for laying dunnage. The condition, properties and intended protective action of the available materials and similar considerations must be taken into account. In many cases, only compromises can be considered, since some fundamental requirements can contradict each other; especially if materials are to assume a number of protective functions simultaneously.

The following guidelines are intended to help make practical decisions. Since not all variants can be shown, the action and decisions taken will need to reflect the given circumstances. How to lay dunnage most appropriately and what materials are to be used depends on the stowage space, the structural design of the cargo transport unit and the restrictions anticipated during transport. These include the climatic zones through which the cargo will travel, changes in weather, storage duration and voyage duration, anticipated mechanical, climatic and biotic shipping stresses etc.

Wooden dunnage is differentiated according to the quantity and thickness of the wood used and the method used to lay it:

- Simple wooden dunnage comprises boards laid out side by side.
- Double dunnage or criss-cross dunnage comprises boards laid at right angles to or obliquely over each other.
- Raised dunnage can comprise planks or squared lumber laid in single layers or a combination of boards, planks or beams laid at right angles to or obliquely over each other. Another good option is to use pallets as stowage surfaces.

The orientation of and space between the wood used depend on the intended protective effect and the nature of the means of transport or the stowage space:

If the main aim is to dissipate moisture or damp, the wood at the bottom must be laid in such a way that water and other fluids are conducted along the quickest route outside or to any available discharge outlets and do not produce any accumulation of damp. It is not practicable to dissipate liquid to the outside in standard containers which have not been structurally modified, since these containers are spray-tight and thus generally prevent water from flowing out freely. If actively or passively ventilated containers can be used, criss-cross dunnage can enhance the ventilation effect. When laying out dunnage, it should be remembered that ships are not constantly on an even keel. They can

be trimmed by the stern or trimmed by the bow. Rolling and pitching cause the deck to slope. These slopes, as well as any special factors in the ship's construction, must be taken into consideration when laying out wooden dunnage. With open containers, dunnage can be laid out transversely. Liquids can immediately flow out when the ship rolls. If the ends of the wooden boards are taken right up to the side rails, load forces are distributed appropriately at the same time. It should be remembered that closed containers are spray-tight and that dissipation of moisture to the outside only happens to a limited degree and then only slowly.

If a good distribution of load forces is the primary consideration, the wood at the bottom must be laid out in such a way that as many load-bearing components of the cargo transport unit are covered as possible.

If good moisture dissipation is as important a consideration as a good distribution of load forces, the best possible compromise must be reached, for instance by laying out the base wood diagonally.

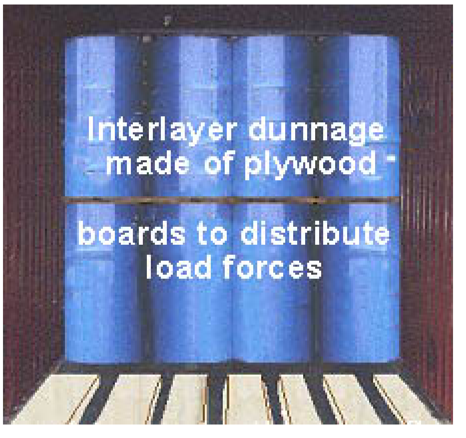
If the most important consideration is to protect against mechanical damage, it is essential that potential shifting or movement resulting from shipping stresses and typical for the particular means of transport are taken into account.

If goods which are sensitive to dirt, moisture or mechanical damage are loaded, additional materials such as mats, jute cloth, paper, sheeting etc. are to be used as required.

If there is a danger of dampness or contamination of the packaging spreading to the contents, dunnage must be laid with special care.

If plastic sheeting and similar materials are used to prevent dampness from penetrating the cargo, their orientation the way they are arranged play an important role. In these cases, consideration must be given to where damp could enter and where it can be dissipated. Under no circumstances must "water pockets" be allowed to form, which would enable collected damp to enter the cargo. Dunnage must first be laid out at the point where most water is able to penetrate.

Interlayer dunnage



Floor dunnage

Laying out floor dunnage to protect from damp in containers will always be necessary when "wet goods" are stowed together with moisture-sensitive goods. Occasionally, criss-cross dunnage and double dunnage will be necessary. Damp must be prevented from infiltrating sensitive cargoes by laying dunnage at appropriate heights and using additional material, e.g. plastic sheeting. In box containers, it is generally more appropriate to lay out wooden dunnage in a longitudinal direction, because of the distribution of load forces and the use of ground conveyors. On open containers, it should be laid out transversely. In both cases, the load-bearing components must be bridged for heavy packages so that the permissible line load is not exceeded.

On open chassis and trailers, wood must be laid out to distribute load forces in such a way that the load is taken by the vehicle's chassis. Walking boards made of glued-laminated plywood at a size of 1 m x 2.5 m, for instance, or wooden boards of a suitable length and adequate dimensions are very suitable for this. Floor dunnage made of wood or plastic sheeting is used to prevent contamination. Since it is possible that cargo transport units can be transported on deck, sufficient protection against damp must be ensured. When distributing load forces, the vehicle chassis and cross members must be covered.

Floor dunnage is very often not needed for freight cars with a wooden floor. If there is a risk of damp infiltration with moisture-sensitive cargoes, appropriate measures must be taken. On covered freight cars, the preferred orientation of the wood is longitudinal, in the door area it is transverse. On open freight cars and freight cars with sliding walls, wood is preferably to be laid out transversely for loading and unloading with ground conveyors. Exceptions to this must be made when end-loading platforms are used. The design of the chassis and of the side rails and cross members must be taken into account with regard to the distribution of load forces. Here, inexpensive materials such as paper, plastic sheeting etc. are sufficient for protection against contamination.

What has been said about freight cars applies in principle to cargo transport units for road transport. On box bodies, however, wood should always be laid longitudinally where possible, for handling reasons.

To be able to effectively protect cargo before packing and after unpacking cargo transport units, dunnage can also be required in stores, sheds, warehouses, hangars and open areas. This can be for leveling out storage areas, protecting against damp and dirt or for distributing load forces. The orientation should be suited to the transport paths and the equipment used. The materials used must be able to provide the necessary protection. Especially on open areas, weather changes such as rain, snow, ice etc. must be taken into full account. Other factors to consider are bacteria on the ground and rot pathogens which could damage the cargo.

Side dunnage has similar functions to floor dunnage:

- Protection against damp or moisture penetrating from the side as a result of sweat or leakage from other cargo, but also protection of other cargo or of the means of transport against liquids escaping from the side of a load.
- Protection against soiling and contamination on the sides, both of a single load against other loads or from parts of the means of transport, or protecting the latter against a specific load.
- Protection against mechanical damage or other damage, such as chafing, tearing, chemical reactions etc. both with regard to a specific cargo and to other cargoes or parts of the means of transport.

The same materials are used for lateral dunnage as for floor dunnage. The use of wooden dunnage, however, is less significant.

To protect against damp or moisture or harmful dust penetrating from the sides, watertight and dust-tight materials such as plastic sheeting, oiled paper and tarpaulins are to be used. Under certain conditions, canvas and mats should also be used, but never wrappers or paper.

Sweat formation always occurs when temperature differences are too high, either with a positive temperature difference against the load or a negative temperature difference against components of the means of transport. For further information on this, see section 10.3.4 "Sources of sweat". The risk of sweat is higher on cargoes with a high water content. If there is a risk of cargo sweat (section 10.3.6.4) and the cargo is sensitive to moisture, it is urgent that a corrosion protection method is used (see http://www.tis-gdv.de/tis_e/verpack/inhalt1.htm). Wrapping cargo in plastic sheeting can have the opposite effect to that which is desired. Since hot air rises, water vapor can condense under the sheeting.

Practical experience shows that wooden dunnage boards, wooden boards, mats etc. provide good protection against mechanical damage. Whether or not it is necessary to use additional materials depends on the particular circumstances.

Top dunnage is laid to prevent the consequences of leakage, sweat formation, bad weather, vertical shipping loads etc., which could damage a particular cargo or the cargo transport unit and its components.

The main functions of top dunnage are:

- Protection against damp or moisture penetrating from the top or escaping upward
- Protection against dust or substances which threaten contamination or chemical reactions, either penetrating from the top or escaping upward
- Protection against mechanical damage anticipated to arise from above or acting in an upward direction

All previously described materials can be used as top dunnage materials.

To protect against damp or moisture penetrating from the top, or to prevent moisture from being allowed to permeate upward, plastic sheeting, oiled paper, tarpaulins and other watertight materials have proved themselves in practice.

If only small quantities of moisture are anticipated, the best materials to use are ones which can absorb small quantities of water.

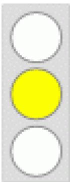
The type of nonwoven fabric shown can absorb relatively large quantities of dripping water. Since the weight increases when these properties are used, it must be attached carefully.


Special absorbent, nonwoven fabric cover as top dunnage

When using watertight materials, it is essential that liquid which has collected in depressions (water pockets) is prevented from flowing into the cargo when the vehicle moves. For this reason, plastic sheets etc. must overlap each other properly or wood, cargo items or the stowage method must be used to create an appropriate slope. Respiring organic goods, such as tobacco, coffee, cocoa, fish meal etc., which are transported in passively ventilated containers, must not be covered with airtight materials or materials impervious to water vapor.

If top dunnage is used to protect against contamination or to prevent harmful chemical reactions, the same principles apply as for protecting against damp, but the materials must be dust-tight and chemically compatible. A certain degree of air circulation must also be ensured here occasionally.

Interlayer dunnage variously has the functions of floor dunnage, side dunnage or top dunnage, depending on how it is arranged. It is laid between two different batches or individual goods in a batch or load type.




Interlayer dunnage on a load of pails

In some cases, it simultaneously helps secure the load by increasing friction, improving the distribution of load forces or improving the stability of the load.

All materials which have been described can be used. In addition, powdery substances such as talcum powder. They are introduced in the form of an intermediate layer or are sprinkled between layers, to prevent loads from sticking together, e.g. with bales of raw rubber.

Interlayer dunnage comprised of mats provides adequate firmness and protects against mechanical damage.

Here, wooden dunnage boards were used to create a level packing surface. But will the bottom left carton of the load be able to bear the load packed on top of it? This ought to be supported from beneath using vertical squared lumber.


Interlayer dunnage made of wooden dunnage used as a leveling aid

Inadequate interlayer dunnage of wooden dunnage boards

Further measures should to be taken here as well. As in so many cases, inadequate unitization is responsible for additional work - which sadly is not very productive in this case.

Left and bottom:
Missing interlayer dunnage

In both examples, the use of interlayer dunnage is urgently recommended.

4.2.4 Basic stowage methods

4.2.4.1 Basic stowage methods, Part 1

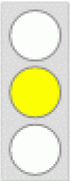
Stowage instructions and basic stowage methods

To be able to provide and follow appropriate instructions, it is necessary to be familiar with some of the fundamental concepts and principles which apply in this field. To ensure that they are well understood, some of them will be explained here.

"***Stowage for ready access***" or "**Packing for ready access**" means that a load must be immediately accessible. Ease of access may apply to a specific (intermediate) destination, i.e. that a given load must be readily accessible in for instance Bremen and can be unloaded without the need to move other loads.

Section 4.3.7 of the CTU guidelines state:

> *Dangerous cargoes consignments which form only part of the load of a CTU should, whenever possible, be packed adjacent to the doors with markings and labels visible. Particular attention is drawn to 3.3.1 concerning the securing of cargo by the doors of a unit.*



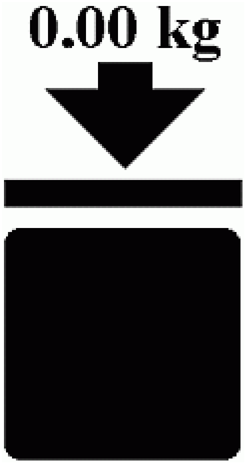
**Cases with class 1.4G airbags:
stowed for ready access**

The amber light has been selected because the load has not yet been adequately secured.

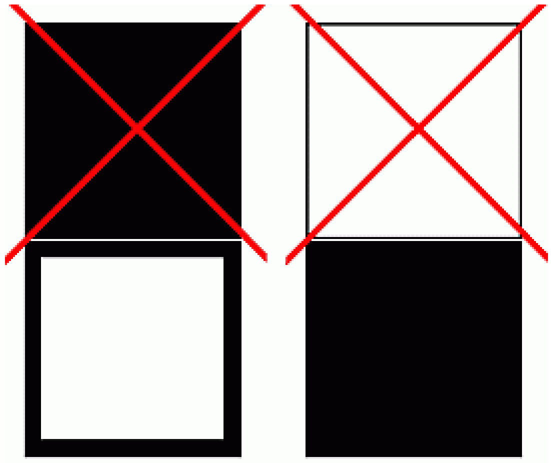
CAP products in the European Community which are subject to customs checks should also be stowed for ready access, so that customs staff have immediate access to the goods. This avoids the need to restow:

The container had to be restowed to make the container door accessible and the cargo had to be partially unloaded to allow access to the CAP products for a customs inspection.

"***Top stowage***" (occasionally "***on-top-stowage***") means no further items are stowed on top of the load. This instruction is not to ensure that a batch should be readily accessible, but is issued because packages are particularly sensitive or fragile. If stowage of this type is required, appropriate indications must be attached to the packages. Written instructions such as "Do not overstow", "Please load on top" etc. are not necessarily universally understood. Sensible, comprehensible markings can be more effective.



Symbol based on ISO

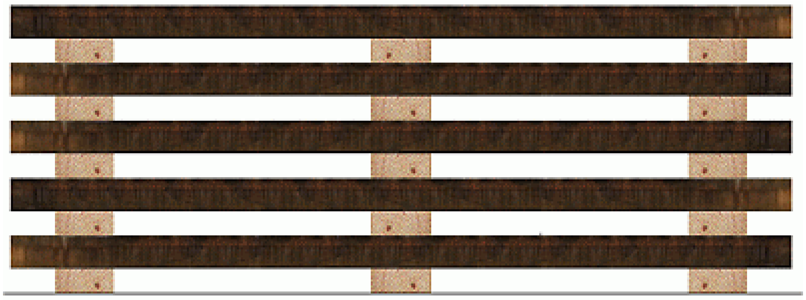


Alternative marking suggestions

The original ISO symbol should be known universally. It must therefore be assumed that this symbol is the most likely to be understood.

"***Stowing or packing correctly for a fork-lift truck or a crane***" means that appropriate arrangements must be made to ensure that the goods can be lifted by a ground conveyor or lifting gear without requiring special preparation and without any time delay. The dimensions, strength and loading capacity of the aids used, such as squared lumber, wooden dunnage boards etc. must ensure that the goods do not suffer any damage during shipping. If necessary, stowage surfaces must be prepared with walking boards, boards, cargo items with a high loading capacity or other usable aids, so that work can be carried out safely and the batches that have already been loaded can be overstowed with other loads.

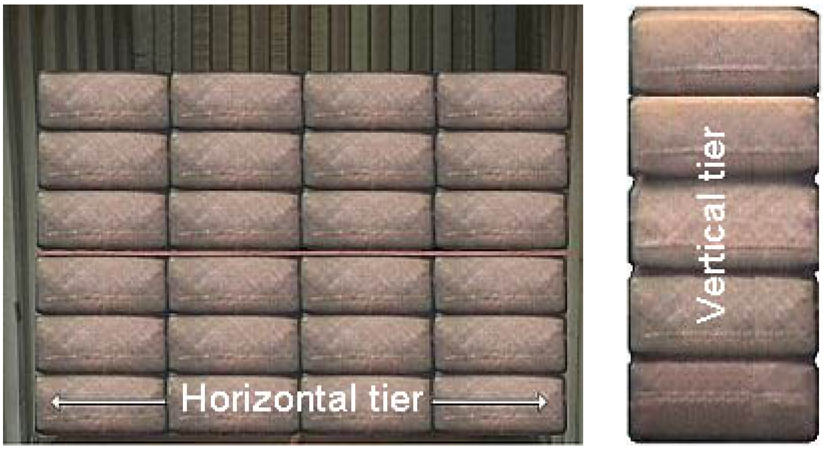
Correct stowage suitable for handling with fork lift trucks in a box container



Cargo stack suitable for handling with fork-lift trucks and cranes

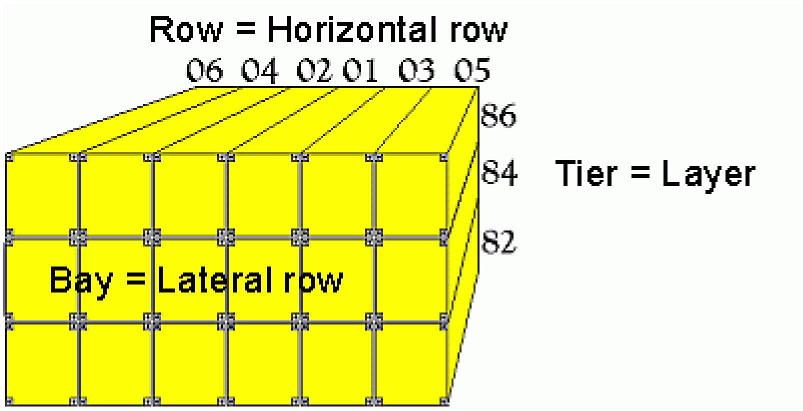
Bottom and intermediate dunnage must be arranged so that forks, strops, chains, claws and similar cargo handling equipment and slinging equipment can be used without any problems.

Tier means a layer or stack. It can mean either horizontal layers of cargo or cargo items stowed vertically one above the other. If circumstances do not make it clear from the outset what type of layer is meant, it makes sense to distinguish between a ***vertical tier*** and a ***horizontal tier***.



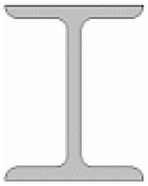
Horizontal and vertical tiers

The stowage position on board container ships is generally documented according to the bay-row-tier system or the bay-tier-row system. In this specific case, "tier" designates the horizontal layers of containers. Layers are counted from the bottom to the top.

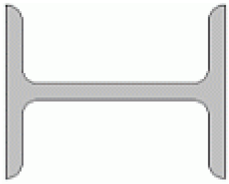


Extract from a bay plan showing the containers loaded on deck

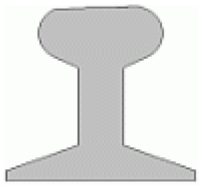
Loaded upright or ***loaded on its side*** relates to the shape of the consignment items. In most cases, the meaning is clear.



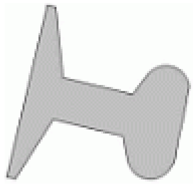
Beam is upright



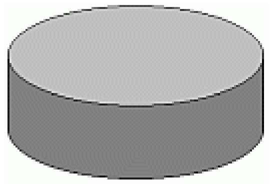
Beam is on its side



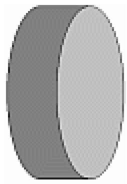
Rail is upright



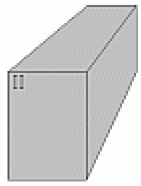
Rail is on its side



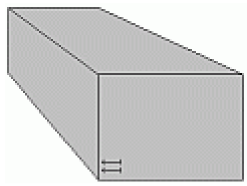
Disk is upright



Disc is on its side

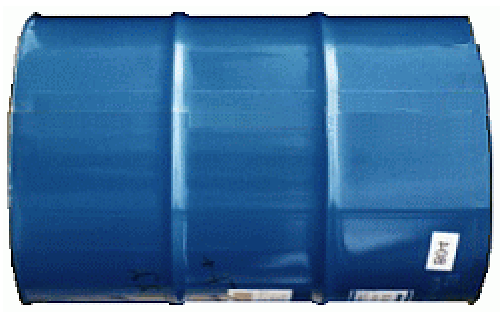


Box is upright



Box is on its side

Drum is upright



Drum is on its side

The same applies for wheel rims, pipes, steel bars, narrow wire rod coils and other loads. It is also rare for these to be confused.

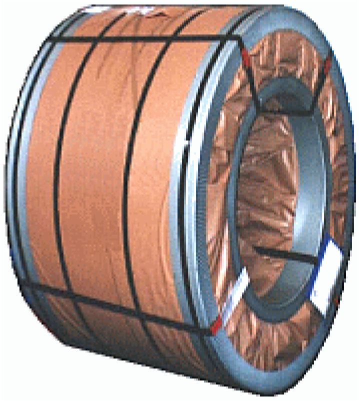
With cylindrical, or roller-shaped goods, the expression "upright" should really be used uniformly. Such cargo items are generally understood to be "upright" if

- the axis is vertical and the length of the axis is greater than the diameter or
- the axis is horizontal and the length of the axis is less than the diameter.

Paper roll is upright

Gas cylinder is upright

Coil is upright



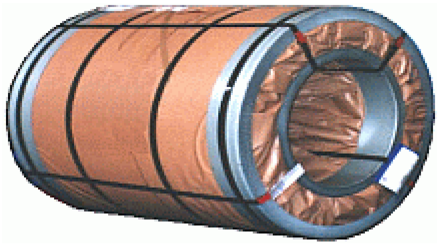
Coil is upright

Tire is upright

The expression "on its side" also has a standard meaning for the same goods. By definition, cargo is "on its side" if

- the axis is horizontal and the length of the axis is greater than the diameter or
- the axis is vertical and the length of the axis is less than the diameter.

Paper roll is on its side



Coil is on its side

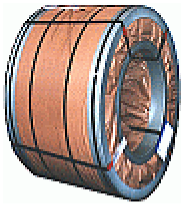
Gas cylinder is on its side

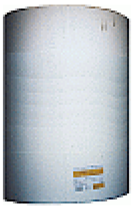
Coil is on its side **Tire is on its side**

Differences in understanding of these terms, sometimes regional, however, can lead to errors and misinterpretations and thus incorrect stowage.

Another problem arises if the length of the axis and the diameter are almost the same size. This can easily lead to misinterpretations of the terms in practice:

Is the coil upright or on its side?





Is the roll upright or on its side?

Incorrect expressions in the loading instructions or an incorrect interpretation of correct instructions frequently lead to damaged cargo. Such damage can be avoided if a reference is made in the stowage instructions to the orientation of the axis. Instead of the formulations "Load rolls upright" or "Load rolls on their sides", the expressions "Roll axis vertical" ("eye to the sky") or "Roll axis horizontal and transverse" or "Roll axis horizontal and longitudinal" should be used.

Misleading formulation	**Clear formulation**
... load so that	... load so that
Wire rod coils are upright	Ring axis/winding axis positioned vertically (English: "eye to the sky")
Wire rod coils are on their sides	Ring axis/winding axis horizontal (English: "eye to lie") or even better: ... Ring axis horizontal longitudinally...or horizontal transversely
Cylinders are upright	Cylinder axis is vertical
Cylinders are on their sides	Cylinder axis is horizontal, or even better: Cylinder axis is horizontal and longitudinal Cylinder axis is horizontal and transverse

As already mentioned, the terms "upright" and "on its side" are clear for most cargo items such as billets, pipes,

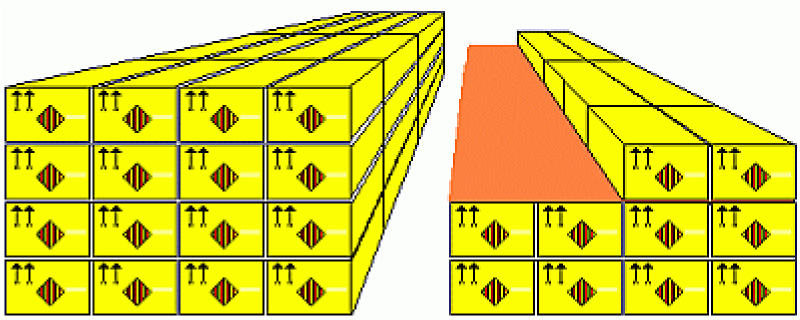
profiles, bars etc., but it can be necessary in certain cases to provide or request more precise stowage instructions, such as "lying on its side" etc.

4.2.4.2 Basic stowage methods, Part 2

Continued from Section 4.2.4.1

To prevent subsequent claims, always ask if anything is unclear. It is more cost-effective to obtain precise instructions from a superior or to make a telephone call to the customer than to lose one's reputation or to have to answer a claim for damages. In most cases, it is sufficient to use two arrows pointing upward to indicate that goods are to be transported a particular way up.

Stacking means loading, packing or stowing packages in layers so that the edges of the packages lie flush above each other.

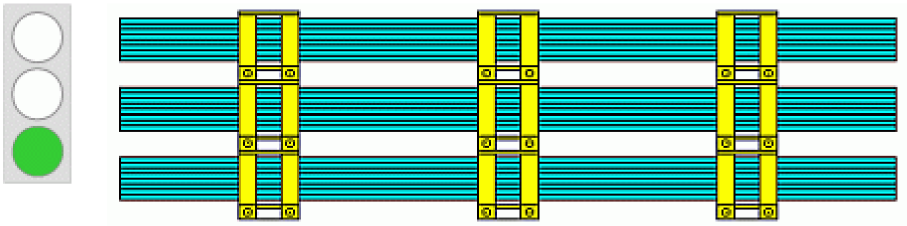


Corrugated board cartons stacked with and without a hardboard anchor

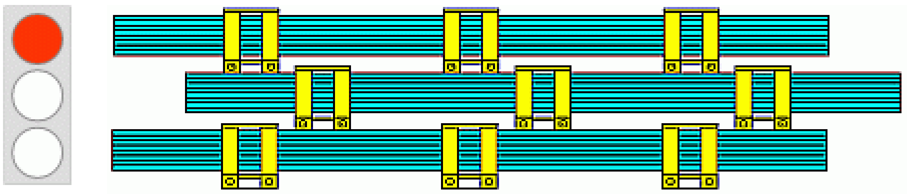
Pressure-sensitive cartons with homogeneous dimensions must always be stacked carefully ensuring that the sides and end faces lie flush. This ensures that only the load-carrying vertical sections are subjected to loads. When using cartons made of corrugated board, it is essential to check where possible that the flutes of the boards are vertical. If it could be disadvantageous that individual packages are not firmly connected to each other, anchors made of materials with a large surface area, such as hardboard, paperboard, plastic sheeting etc., are to be introduced during stowage.

Stacked cartons, with and without plywood anchors

Wall boards and ceiling boards, plastic profiles and similar loads generally have single or double belt battens as "built-in packaging". To prevent any harmful loads from being applied to the boards themselves, the belt battens must be stacked flush on top of each other, and not for instance staggered to save on stowage space. Load securing material must also be attached to these points.

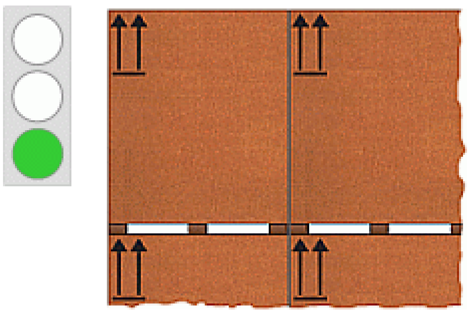


Ceiling boards - loaded correctly, packed one above the other

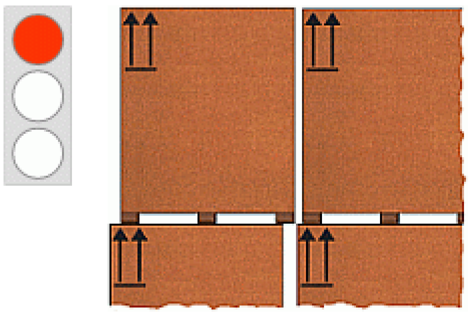


Ceiling boards - loaded in a staggered pattern and thus incorrectly

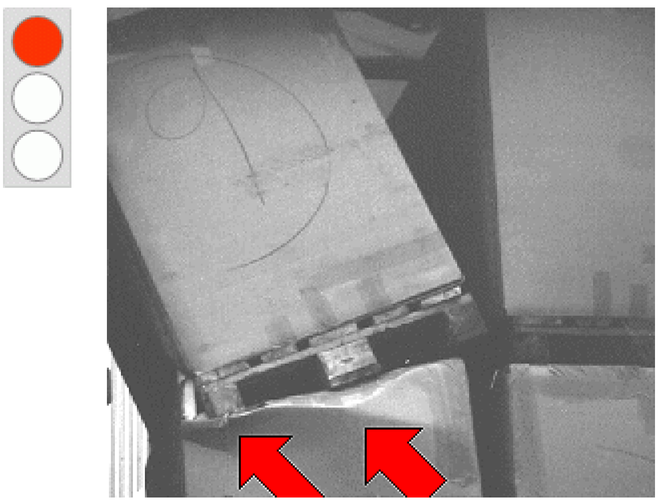
For particular loads, ***stacked stowage*** is an essential requirement, e.g. for pressure-sensitive cartons. In this case, any loads which arise must always be directed onto the load-bearing parts of a package. Even the smallest deviation from the vertical position can cause damage to the cargo.



Correct: Packed edge to edge



Incorrect: Untidy packing



Damage caused by incorrect stacking

The risk of packing errors can be avoided by using adequate interlayer dunnage.

Indonesian tobacco bales also demand correct "stacking". The only intermediate layers which are permitted are: plastic sheeting, kraft paper and other similar materials which can be used to "anchor" the layers to each other. Despite not being bound tightly, the stack as a whole is comparatively stable.

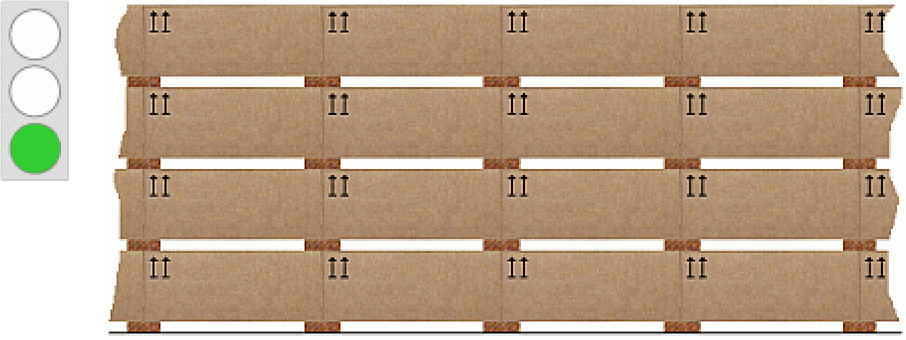
Possibility of ventilating Indonesian tobacco bales with rolled up mats. Floor dunnage made of wooden dunnage boards.

If gaps need to be left for reasons of ventilation or small gaps are required for stowage considerations, they can be achieved by using rolled up mats or equivalent materials.

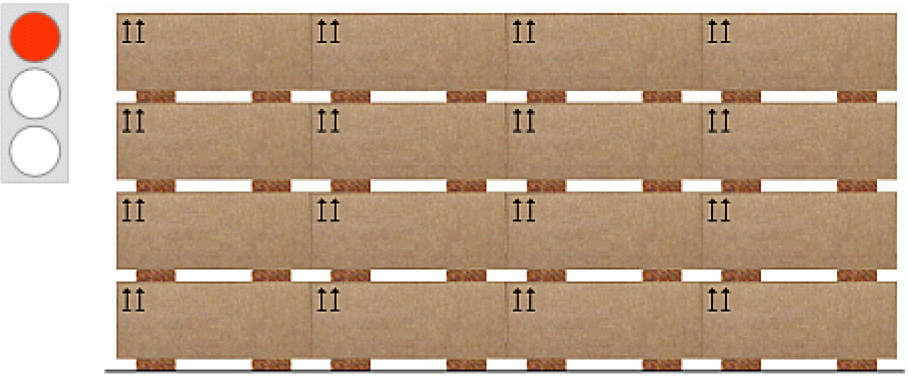
Narrow lattices and laths to ensure air circulation

If only narrow lattices, laths, boards or other strip-shaped materials can be used to ensure adequate air circulation, it must be ensured that they are placed on parts of the load which have sufficient load-bearing capacity.

With cardboard cartons, the load-bearing points are vertically below the side walls:



Correct: The wooden supports are placed on the load-bearing parts of the cartons, i.e. the sides



Incorrect: The wooden supports are placed on non-load-bearing parts

Tightly filled paper bags or sacks should be stacked in the same way. If the bags do not completely fill a hold or do not form a complete transverse tier, a sufficiently stable stack or interconnection of bags or layers can be achieved by inserting wooden dunnage or paper anchors or similar materials.

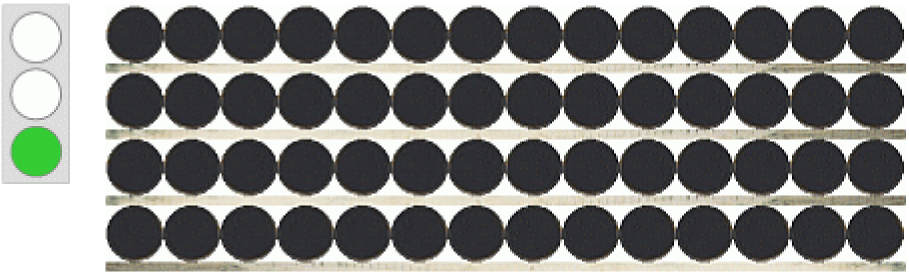
In most cases, it is sufficient to just insert the anchors in the top layers and/or on the sides; Generally, segregation material, dunnage and load securing material should be used sparingly, both for reasons of expense and to prevent stowage loss.

If dunnage has to be laid because "wet cargo" has to be packed together with dry cargo in a container, the dunnage must be laid without large gaps, otherwise, tightly filled paper bags and similar loads could burst or tear and could "bleed".

Sufficient floor dunnage prevents the bags from "bursting".

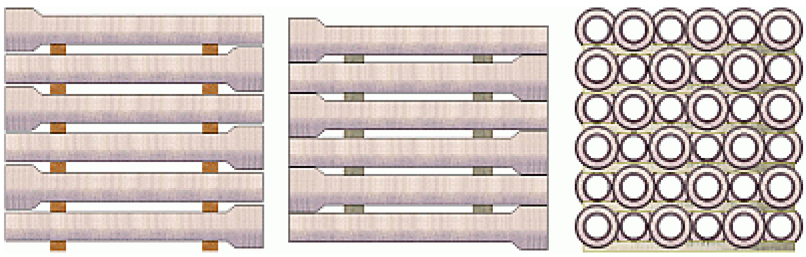
Insufficient floor dunnage makes it easy for the bags to "burst"

High load levels are produced when stowing cargoes in layers with intermediate layers made of squared lumber or wooden dunnage, since only linear bearing surfaces are produced in the area of the bottom and intermediate layers. Only cargoes insensitive to load forces may be stowed in this way. Harmful pressure can be reduced to an acceptable level by using relatively soft wood or by using intermediate layers made of rubber.



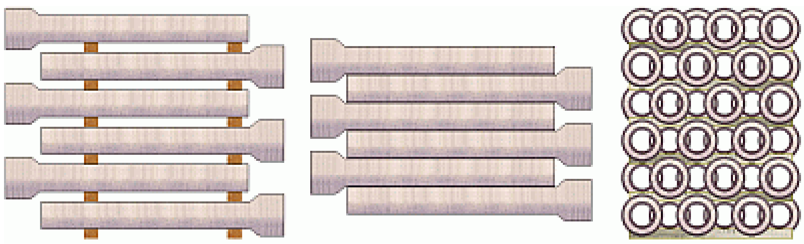
Stacking cargo with a sufficient loading capacity in layers

The pressure-sensitivity of fiber cement pipes or the susceptibility of ceramic pipes to breakage must be taken into consideration when selecting the type of dunnage:



Side view **View from the top** **Front view**

Stowage of socket pipes in layers and in alternate orientation



Side view **View from the top** **Front view**

Stowage of socket pipes in layers and in alternate orientation

All strong and resilient goods of various shapes or sizes can be packed in a

cross-tie stow. Remaining gaps must be filled. Wooden dunnage and similar intermediate layers should also be used as anchors. The need to bridge or pad out stowage gaps can result from a difference in the dimensions of cargo items.

In principle, this involves the cargo items ***interlocking*** with each other. It can generally be used to minimize the effort required for securing cargo. Methods like this improve the stability of the cargo. But, as we have said: This method may only be used with resilient goods.

A ***complete transverse cross-tie*** refers to stowage in which goods fill the stowage space from side wall to side wall. Anchors do not need to be inserted if equivalent measures are taken. This stowage method is suitable for all means of transport having load-bearing side walls or with low lateral stresses, e.g. in rail transport. If the walls of a cargo container are not sufficiently strong, the cargo items must be stowed as a cross-tie, interconnected with anchors or secured using other special measures. It should always be considered that the speed of unloading can be increased by selecting the right anchor materials. The use of mechanical aids should be encouraged and not hindered

in any way. Some examples of a complete transverse cross-tie have already been provided under the other stowage methods. The following warning must be taken seriously: "Complete transverse cross-tie stowage is only safe if the sides of the loading space can withstand the load forces!"

Special care is required when loading curtainsiders, trucks with tarpaulins and roof bows, open-sided containers etc. Vertical lateral tiers can be secured well on the "open" side, e.g. in the direction of a container door, by staggering the layers backward as the tier increases in height. The lateral tiers are then no longer vertical but at a slight angle to the vertical. A gradient of around 10° is recommended. At a stowage height of 2.5 m, the top layer is offset from the bottom layer by about 0.40 m.

Diagonal stowage can be practicable under certain circumstances, from the point of view of loading and unloading, on flatracks, trailers, container bolsters, trucks, certain types of freight car and similar vehicles, so that a number of teams can work at the same time. With this method, cargo of the same type or goods destined for the same recipient are loaded diagonally, to enable the cargo items to be accessed as quickly as possible. In contrast to conventional ship cargo, all goods must be destined for a single place of unloading. Onward transport with remaining diagonal load blocks is not possible.

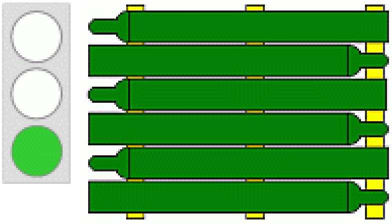
The term ***bilge and cantline*** refers to a loading method in which packages are stowed or fitted into indentations produced by the round or rounded shape of other packages.

Genuine bilge and cantline stowage "on the quarter" is produced when stowing wooden barrels. This stowage method is only used very rarely nowadays.

Wooden barrels stowed with the bilge and cantline method

There are some modified methods for stowing drum and barrel loads in containers, which are to be found in the section dealing with the loading and securing of drum loads. The term "bilge and cantline" is usually also used to mean "bilge and cantline on the quarter", although this is not strictly correct.

Gas cylinders stowed with the bilge and cantline method

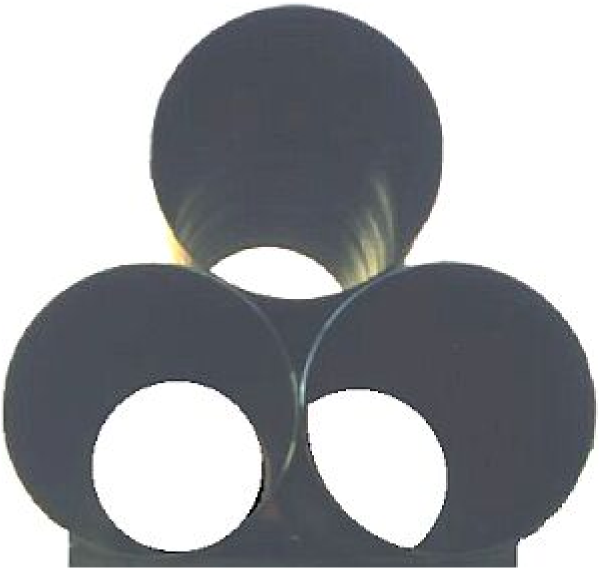


Even better: Stowed bilge and cantline and with alternate orientation

The figure on the left is a good example of how thin rubber nets are used to increase friction. The alternate orientation method makes it easier to load the cylinders with other goods and reduces the overall risk of damage.

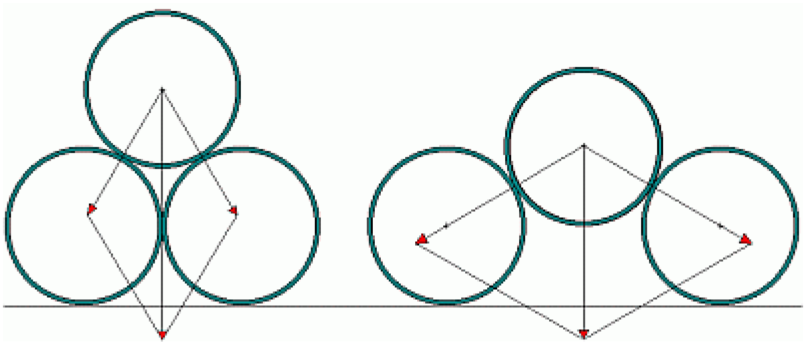
4.2.4.3 Basic stowage methods, Part 3

Continued from Section 4.2.4.2



Pipes stowed using the bilge and cantline method

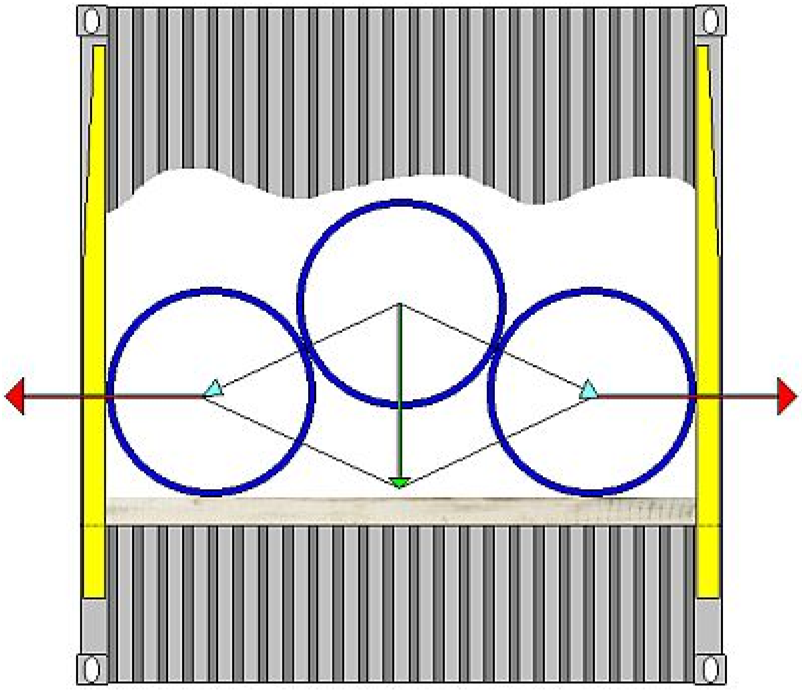
If sensitive cylindrical cargo is stowed using the bilge and cantline method, the load forces are transferred over two load-bearing lines onto the cylinders stowed below. The cylinders in the bottom layer only rest on one load-bearing line. If wooden dunnage or squared lumber is laid as floor dunnage, only load-bearing "dashes" are present for each cylinder, which can cause harmful load forces. Items stowed using the bilge and cantline method exert considerable forces on the layers below them as a result of their opening angle. Only precise stowage can minimize these forces.



The lower a package lies in the gap, the greater the opening angle and therefore the greater the forces transmitted

It should be remembered that at an opening angle of 120°, a package already exerts a force of double its weight on the underlying packages and at 151°, this force is even four times its weight. If packages of this type are in turn bearing heavy loads, they will exert extreme downward forces. On welded pipes, the welded joints should not lie on the contact lines between the pipes. If cargo items do not fit exactly into the vehicles, improper stowage can result in gaps being left between the goods, which results in large opening angles and resultant forces. If gaps cannot be avoided, they must be left on the outer sides and padded out accordingly.

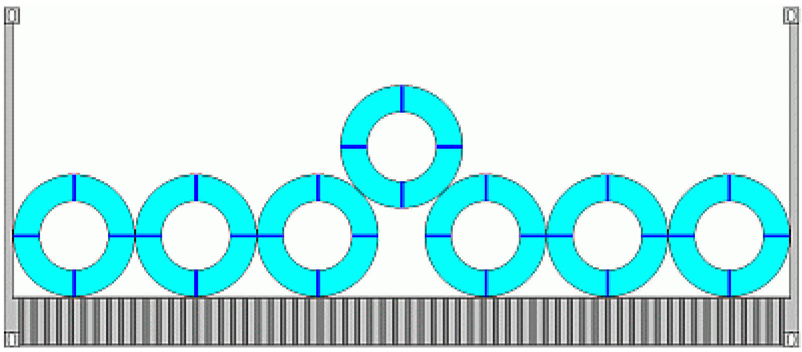
If cylindrical goods are loaded with stowage gaps and stowed with the bilge and cantline method, a cargo item which protrudes low into the cantlines of the underlying layer could exert considerable lateral forces on the stanchions or other edges of the loading area. This would result in damage to the cargo and/or damage to the means of transport.



Load forces on other cargo and components of the means of transport caused by the opening angle

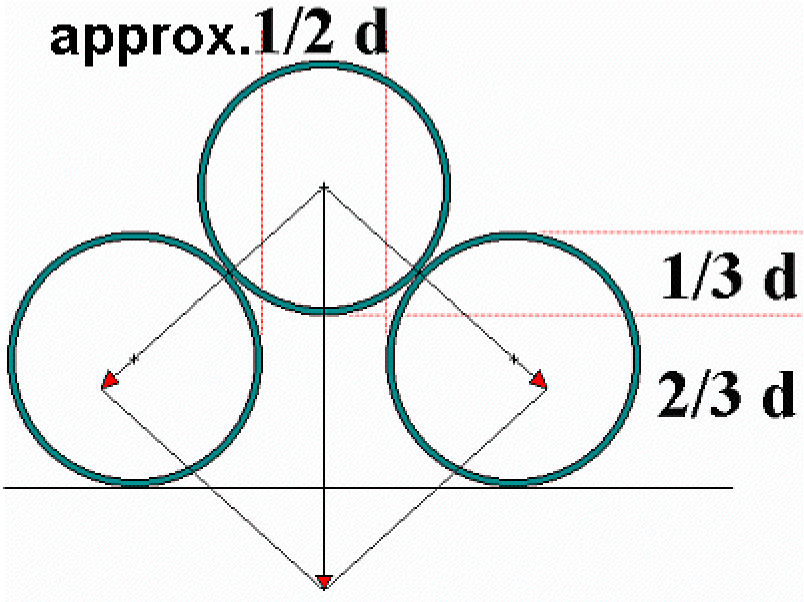
The middle pipe exerts lateral forces (red) as a result of its opening angle, which are greater than its own weight (green).

With resilient cargo items and load-bearing walls of the means of transport, the forces generated by the opening angles can be used to secure the cargo. The best-known example is the locking coil. This method can be used on any type of cylindrical cargo item. This is a good securing method, as long as other cargo items are prevented from riding up elsewhere. If necessary, additional lashing must be used.



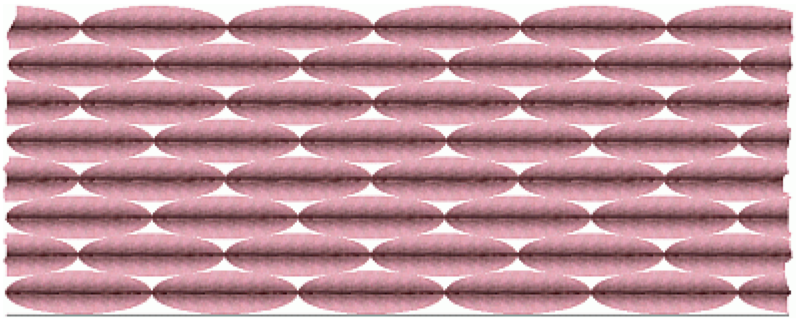
Principle of the locking coil

If the forces exerted by a cargo item are too great, they can damage other goods or components of the means of transport. The gaps should therefore be no greater than half the diameter of the cargo items. If all the items are of equal diameter, the locking element then protrudes by around a third of its diameter into the cantlines of the layer below.

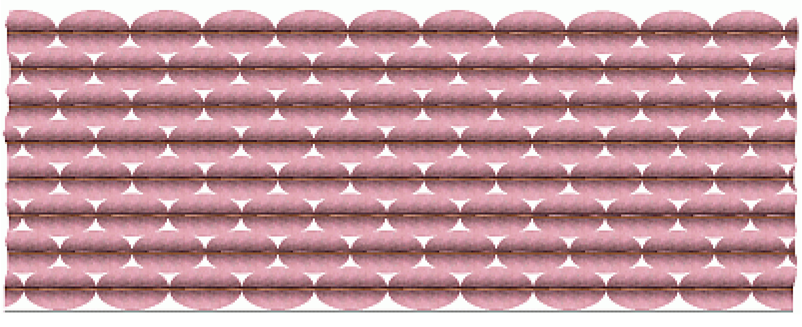


Maximum protrusion for goods stowed with the bilge and cantline method

Other goods can also be stowed using the ***bilge and cantline*** method, e.g. bagged cargo, more robust paperboard cartons etc. Using this stowage method, the seams or edges in all layers will lie in parallel. The packages of the vertical tiers are connected to each other, but not to the packages of adjacent tiers.



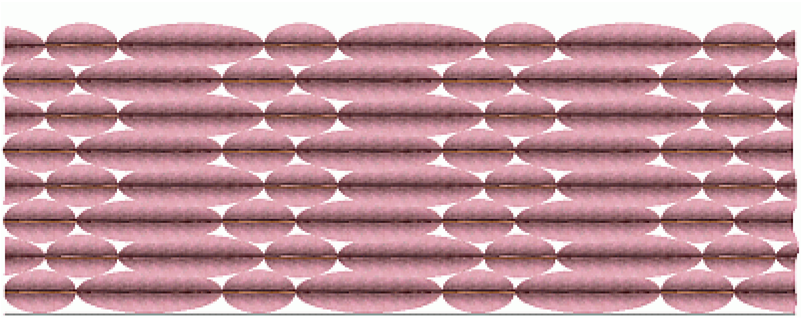
Bags stowed longitudinally with the bilge and cantline method



Bags stowed laterally with the bilge and cantline method

Cartons stowed with the bilge and cantline method

In a ***cross-tie stow***, packages are stowed alternately longitudinally and transversely. In this way, they are firmly interconnected:

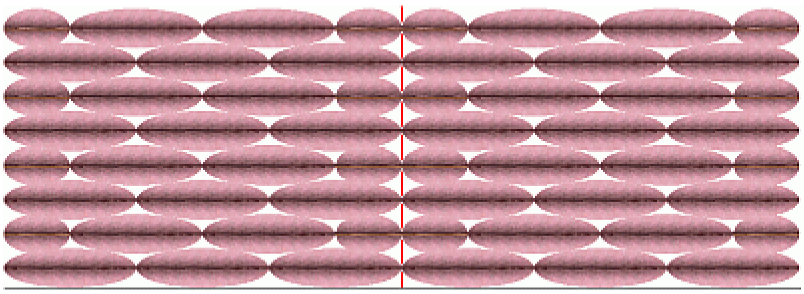


Example of cross-tie stowage of bags

Full cross-tie stowage enables goods to be completely connected to adjacent tiers: Cargo items in one tier extend half-way into the adjacent layer. Full cross-tie stowage can be recognized by the fact that no continuous lines can be seen either longitudinally or transversely. If cargo items have different dimensions, the stow must be arranged in such a way that cargo items which are as flat, long and stable as possible loaded in the outermost tier with the long side pointing into the stack.

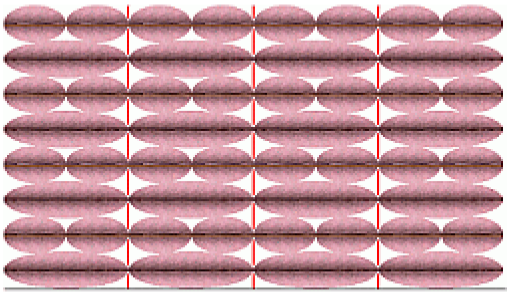
If bagged cargo is loaded in such a way that free-standing tiers remain at the edges, the seams or closures should point into the stacks, as they are weak points of the packaging. If this is not observed, bags can "bleed", which in turn endangers the stability of the stack.

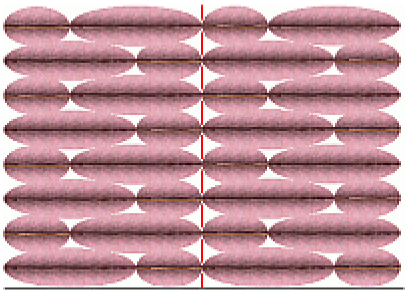
The following illustrations show partial cross-tie stowage, since continuous lines can be discerned in each case. Only the individual blocks are interconnected within themselves. By inserting anchors here, they can be connected to adjacent blocks.



Example of partial cross-tie stowage of bags

Example of partial cross-tie stowage of bags

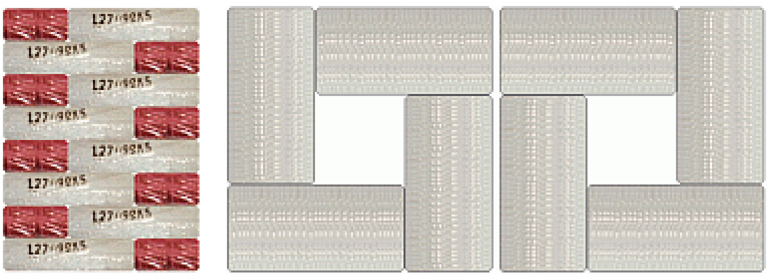




Example of partial cross-tie stowage of bags

Example of bags cross-tie stowed on a pallet and with shrink-wrap

Chimney-style stowage is extremely well suited for forming pre-slung cargo. With palletized bagged cargo, it is suitable for certain bag sizes. The bags are arranged layer by layer so that they overlap around a cavity. The bags are thus connected to each other. This produces a square footprint, which is very suitable for packing containers if it has the correct dimensions.

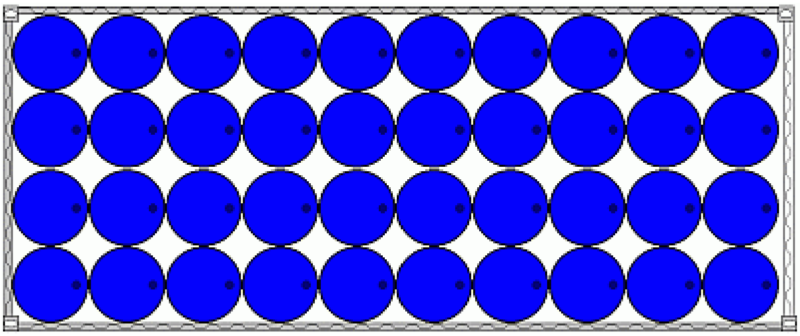


Front view **Layer 1, 3, 5, 7 ...** **Layer 2, 4, 6, 8 ...**

Principle of chimney-style stowage

Nearly all goods can be stacked using the ***bilge and cantline method*** or can be stacked and ***offset***, if sufficient interlayer dunnage is laid, allowing the load forces to evenly distributed, and thus preventing point loading.

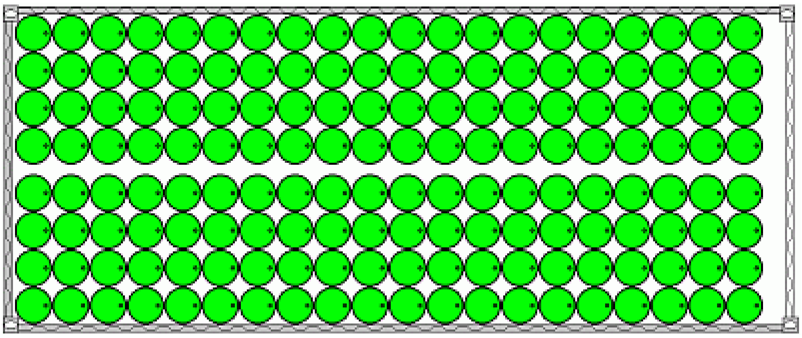
Soldier stow or ***soldier packing*** is used to describe the following arrangement of goods:



Soldier stowage of drums in a 20' box container

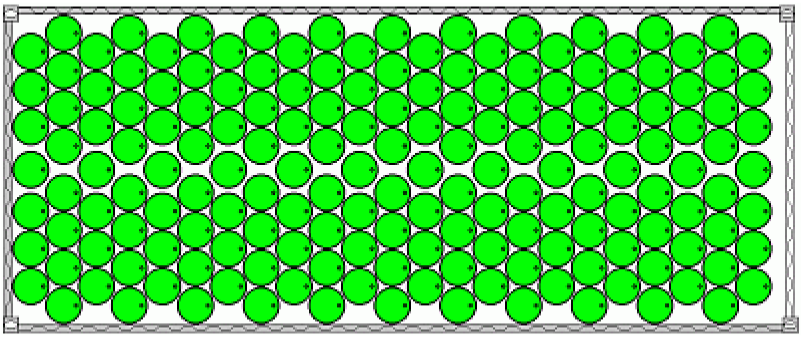
The 20 foot container used has an internal length of 5,895 mm and an internal width of 2,350 mm. The drums packed using soldier stow have an external diameter of 585 mm. Exactly 40 barrels fit into the container using this stowage method.

The same container will also accommodate a total of 160 pails with an external diameter of 290 mm using soldier stow:



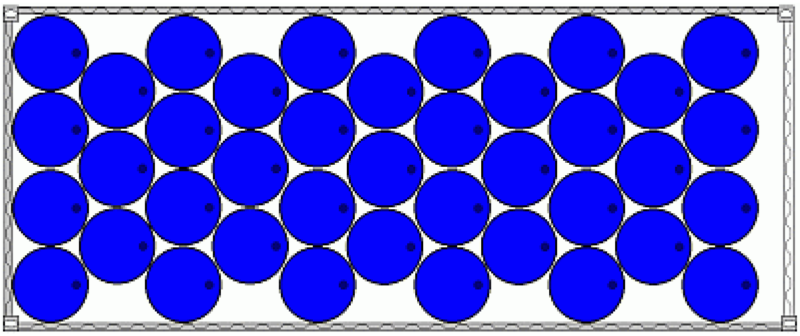
Soldier stowage of pails in a 20' box container

Offset stowage can minimize loss of stowage space, but not always. Offset stowage of the pails with an external diameter of 290 mm, for instance, will allow the container to accommodate a total of 172 pails:



Pails stowed using offset stow in a 20' box container

The same container will only however accommodate 39 barrels with an external diameter of 585 mm using offset stow - compared with 40 when using soldier stow:

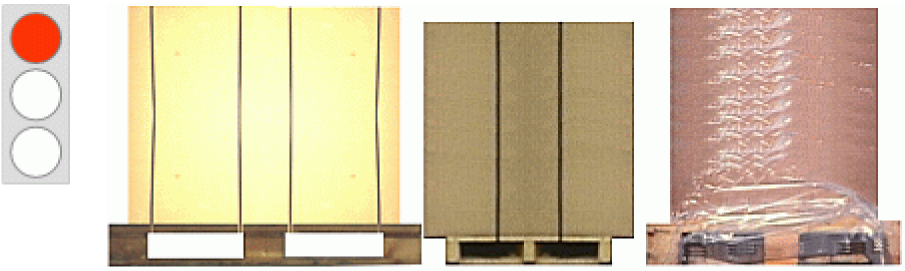


Offset stowage of drums in a 20' container

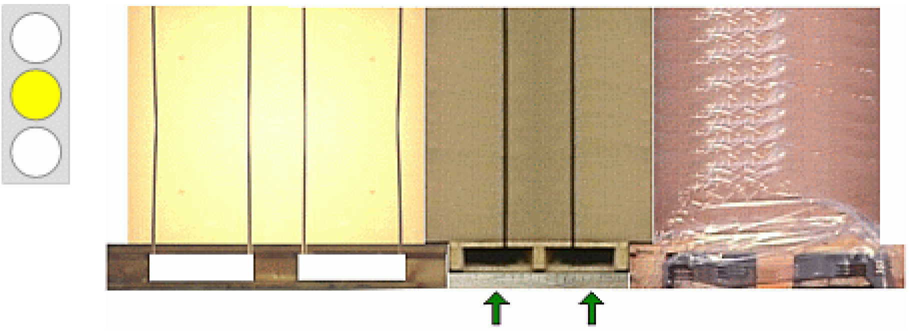
Vertical bilge and cantline stowage would also be a way of describing offset stowage, but it is not (yet) in use as a technical term. The term "vertical bilge and cantline stowage" of drums (or other cargoes) makes it very clear what is meant, however.

Whether stowage space can be saved depends on the dimensions of the goods and the dimensions of the means of transport. More goods can be stowed if the loading areas are large and/or the load diameters are fairly small. This is only sometimes the case for fairly small spaces and large load diameters.

Alternately raising loads can prevent damage, improve the usage of stowage space or save on load securing materials.



Incorrectly loaded pallets make load securing more difficult.

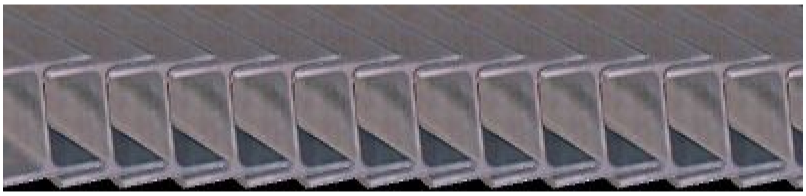


Alternately raising loads reduces the outlay for load securing.

Drums, pails and similar cargo items have construction-related problems. Corrugated drums ride up on the corrugations as a result of transport forces. If closures protrude over the edge of quick lever-closure drums, the drums will snag on the closures. This results in unwanted opening of the drums and/or damage to the drums. Resulting gaps can also lead to further damage. The closures on fiber drums, the handles on drums, pails, cans and other similar containers can cause damage to cargo stored on top of or next to them as a result of high point loading. Alternately raising individual cargo items or groups can reduce the risk of damage. For further information, see the section on drum loads and mixed loads.

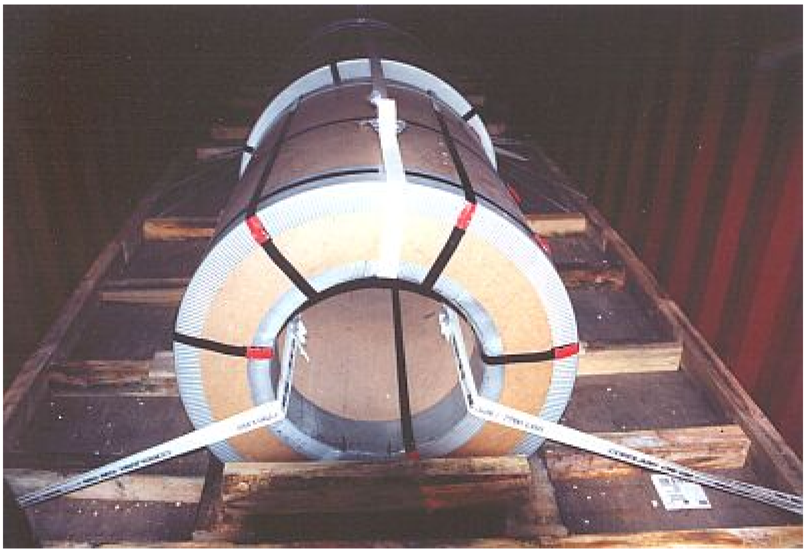
Manual ***interleaving*** of I beams and U profiles is rarely practiced. "Interleaved" loads are often delivered as a bundle, however, and then stacked using normal stowage anchors and squared lumber anchors.

Nested stowage reduces loss of stowage space or can be used to create level cargo surfaces for access with fork-lift trucks. Some variants have their own names. Manually stowing on site is also becoming increasingly rare for this method, as it is growing much more common for cargo to be stowed in bundles beforehand at the factory.



Nested I beams

Face stow refers to the loading of coils, rolls etc., with their axis oriented parallel to the longitudinal axis of the skid or means of transport.



Face stow of coils in a container

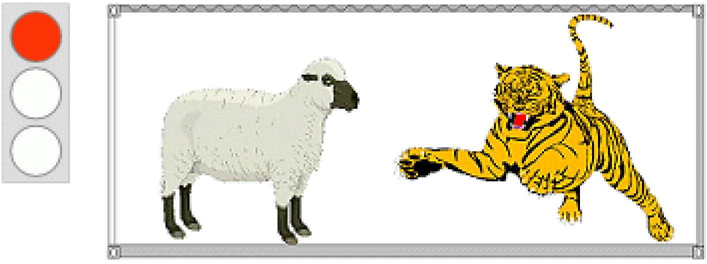
Braiding involves placing ring-shaped loads, such as tires, wire rod coils with a short winding axis etc. in the core of other ring-shaped loads. Braiding has lost its importance through the use of special vehicles and the now common practice of transporting smaller batches in containers. The method is still used, however, on complete loads or fairly large batches.

Braiding of car tires in a 20' container

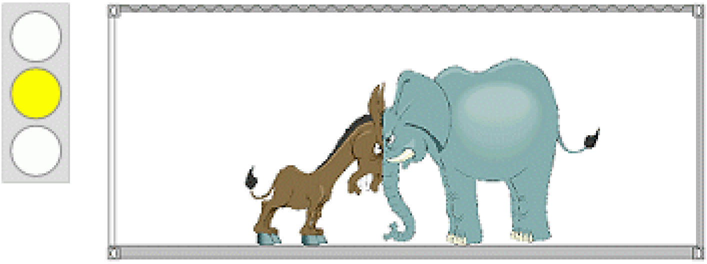
4.2.5 Packing rules

4.2.5.1 Packing rules, Part 1

This section introduces some basic packing rules and prohibitions. It is strongly recommended that staff observe these.

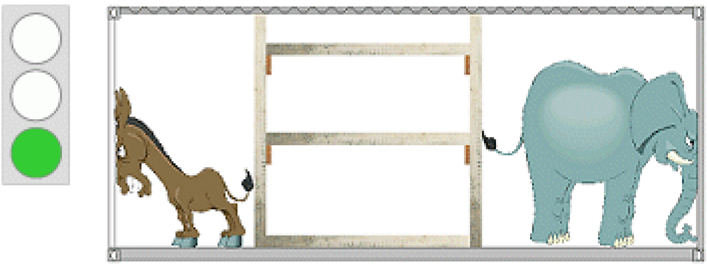


Do not load incompatible goods together!



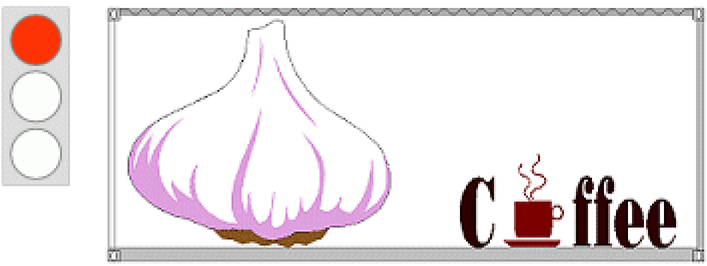
Stowing incompatible goods together is associated with risks!

If it is essential for incompatible goods to be stowed in a single container, the goods must be segregated from each other so that they can no longer cause any damage:



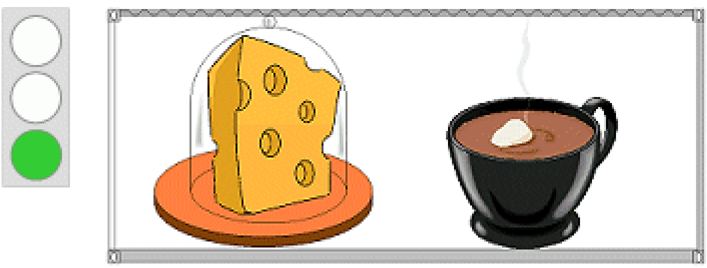
Segregate incompatible goods if they have to be loaded together!

Where such segregation is necessary, the precise method used needs to be chosen on a case-by-case basis. Covering goods with plastic sheeting, wrapping them, introducing barrier layers and similar measures are possibilities.



Do not pack odor-releasing goods together with odor-absorbing goods!

If it is not possible to avoid packing odor-emitting and odor-absorbent cargoes together in a container, they must be isolated from the atmosphere of the hold so that they cannot influence each other:

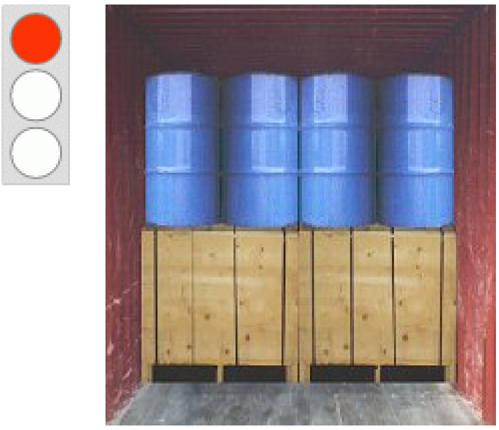


Odor-contamination must be prevented!

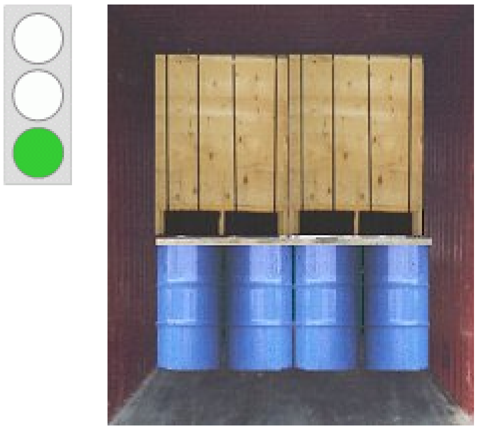
Time is the factor that determines how extensive these measures should be and what segregation materials are to be selected. The longer the duration of the journey or of storage, the more resistant the screening materials have to be against molecular penetration/diffusion.

Do not pack wettening goods together with moisture-sensitive goods!

If, contrary to this rule, liquid cargoes or moisture-emitting cargoes have to be packed into a common cargo transport unit, the moisture-emitting cargoes must be loaded at the bottom:



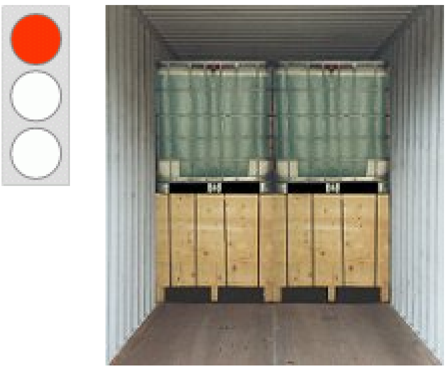
Do not pack "liquid cargoes" on top of "solid cargoes"...



... but do pack "solid cargoes" on top of "liquid cargoes"!

These basic packing rules are also defined in the CTU guidelines. Point 3.2 demands:

> *Heavy cargoes should not be placed on top of lighter cargoes and liquids should not be placed on top of solids. When it is intended that packages are to be stacked on top of each other, attention should be paid to the strength of pallets and the shape and condition of the packages. Attention is drawn to Annex 1 of the IMDG code on stacking tests. It may be necessary in some cases to ensure stability of such a stack by introducing dunnage or solid flooring between tiers of the stow. In cases of doubt, especially with heavier packages such as intermediate bulk containers (IBCs) for liquids, it should be ascertained from the shipper or manufacturer of such packages whether or not they are designed and strong enough to be stacked on top of one another, especially where part of the transport will involve a sea voyage. The center of gravity should be below the half-height of the cargo space.*



Special care is needed with IBCs !

The last sentence in Point 3.2.6 of the CTU guidelines contains a further rule:

The center of gravity should be below the half-height of the cargo space.

The formulation *"Heavy cargoes should not be placed on top of lighter cargoes and liquids should not be placed on top of solids"* does not mean that liquid containers may not be packed next to or behind other cargo items. This will often be the case. Then, depending on the quantity of liquids involved, floor dunnage, raised dunnage or criss-cross dunnage should always be laid below the loads endangered by leaking liquids. For further information, see also the section on "Dunnage" (4.2.3 of the Container Handbook).

Another basic packing rule is:

Do not pack goods which produce dust together with dust-sensitive goods!

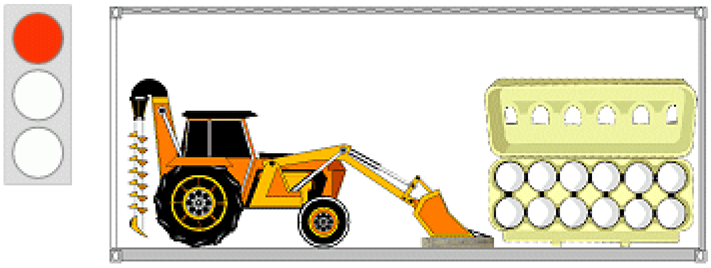
If this packing rule cannot be observed, either the dust-producing goods must be prevented from passing dust particles into the air in the stowage space or the dust-sensitive goods must be protected against the dust particles. How this kind of protection is implemented in practice will depend on the outlay of materials and work. The most cost-effective method should be used. This, however, only applies when the result is neutral - otherwise, the better method must be preferred.

Do not pack dirty goods together with dirt-sensitive goods!

The following also applies here: If this packing rule is unable to be observed, the sources of the contamination must be neutralized or the goods at risk of contamination must be protected by appropriate measures.

4.2.5.2 Packing rules, Part 2

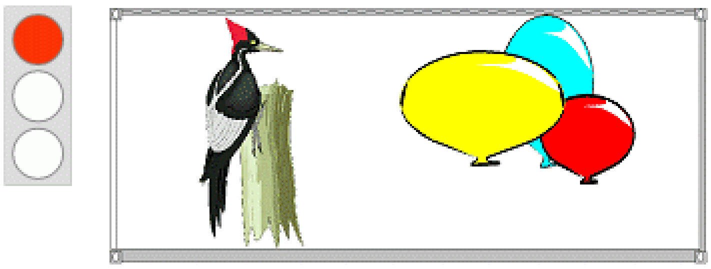
The following packing rule is also not always practicable:



Do not pack pressure-sensitive loads together with loads which exert pressure!

If the rule cannot be observed, steps must be taken to ensure that no pressure can be exerted on the pressure-sensitive goods, or that the pressure can be sufficiently reduced so that it cannot exert any damaging influence on the goods.

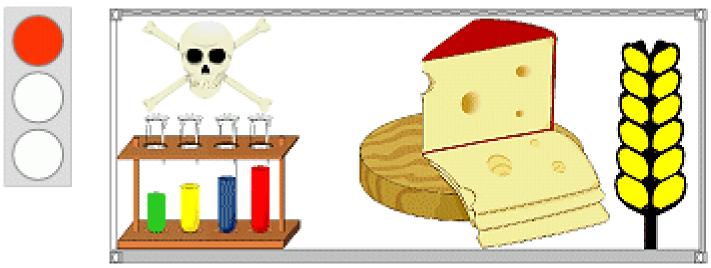
Appropriate measures must be taken if the following packing rule is not complied with:



Do not pack pointed and sharp-edged goods together with goods which might be damaged by them!

Either pad the pointed and sharp-edged parts or protect the sensitive goods against damage by using appropriate packaging or dunnage.

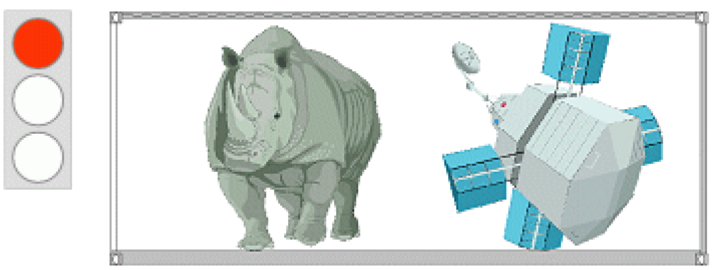
There is no alternative to this packing rule:



Do not pack foodstuffs together with toxic substances!

Failure to comply with this rule puts human life at risk or at least poses a real risk of (serious) damage to health. It may also represent a breach of the law which could lead to criminal proceedings.

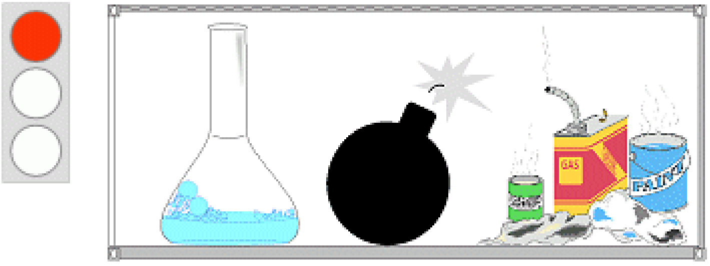
The situation with this packing rule is different:



Do not pack heavy goods with fragile goods!

In practice, this rule will have to be broken more frequently. The risk to fragile goods can be eliminated by taking appropriate load securing measures for the heavy goods.

A very important packing rule is as follows:

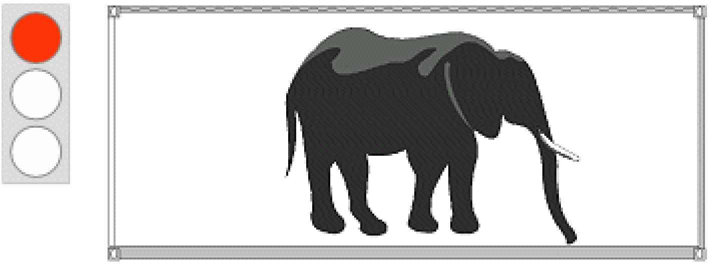


Chemically incompatible goods must not be packed together!

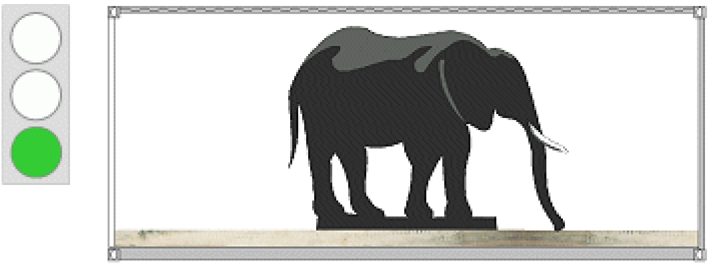
This rule relates primarily to the entire range of dangerous goods - but it also affects perfectly normal goods which can be damaged or have their marketability reduced by chemical reactions. Chemical incompatibility does not always represent a danger to humans, animals or the environment. The reader must understand that this Handbook cannot offer detailed information on loading dangerous goods.

Special packing rules are dealt with in other sections of this book which do not have to be mentioned here. To take an example: cargoes that can be damaged by magnetism, e.g. floppy disks, hard disks etc. must not be packed together with (in immediate proximity to) permanent magnets or similar. For advice on this, see for instance the section on "Packaging and marking".

The following stowage rules are contained in Annex 5 of the CTU guidelines, although with different illustrations, in the form of "Dos" and "Don'ts":

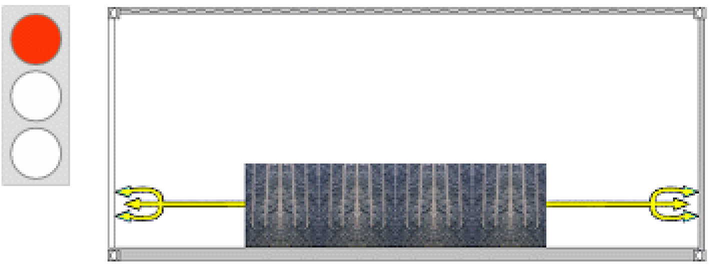


DON'T concentrate heavy loads on small areas of the floor

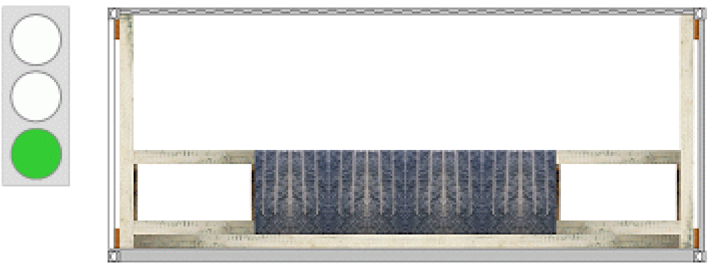


DO distribute heavy loads over a large floor area

Further information on distributing loads is dealt with in the section on load securing aids under "Wood" and under the line loads of containers.



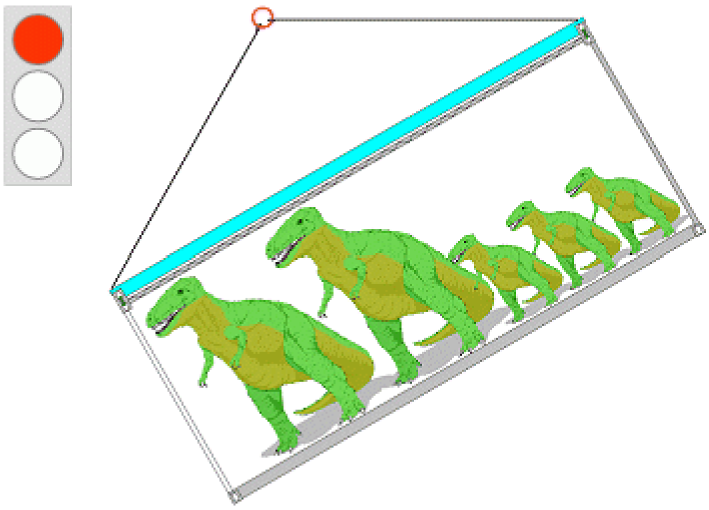
DON'T secure loads in a way that produces heavy forces on small areas of the inside structure of a unit!



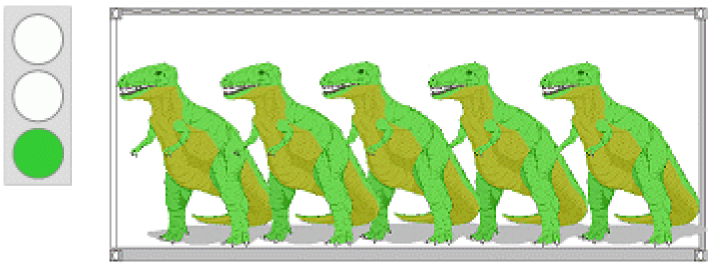
DO secure loads in a way that forces are distributed over a large area of a unit!

This demand can be met by using appropriate squared lumber or other sufficiently strong materials with a large surface area.

4.2.5.3 Packing rules, Part 3



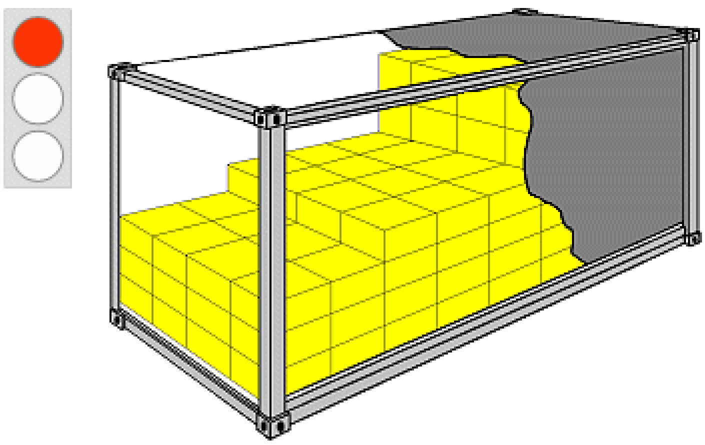
DON'T load with excentric load distribution!



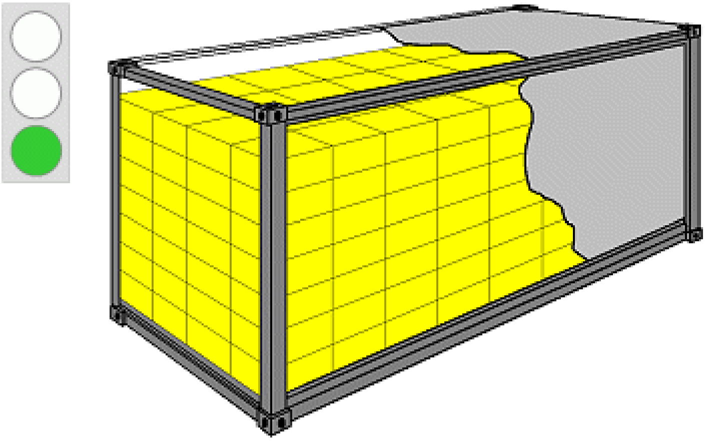
DO load with the center of gravity in the center of the container

Modern container gantries with a high load-bearing capacity and multiple hoisting points can cope with a center of gravity which is off-center. Containers may, however, need to be handled by cranes or gantries with lower pulley blocks which are close together or cranes or gantries with a single hoisting point. This will hinder handling, or even render it entirely impossible. Such slanting loads must also be forbidden for security reasons. In addition, traffic regulations regarding uniform load forces etc. also play a role.

The CTU guidelines also provide the following additional rules:



DON'T build up irregular layers of packages



DO use a block stow when packing cargo

Another recommendation relates to packaging: Material with a non-slip surface should be used to prevent packages from sliding. It has already been mentioned and explained a number of times that the construction of goods and packages plays a key role in load securing.

Finally, a very important stowage rule:

Light on heavy ....

... not heavy on light!

This important basic rule is very often broken:

A heavy case packed on a light carton

If in an exceptional case, heavier goods must be packed on top of light goods, either construct "false decks", or support the heavy goods from beneath or take similar measures.

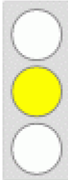
... and one more thing:

CAP products should be loaded in the door area.

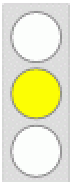
CAP products are of special interest to the Customs authorities. Since a physical check is also made for the existence of goods of this kind, it is sensible to stow them in the door area of box containers. At the very least, they should be packed in such a way that the goods can be inspected by Customs without the need to unpack and re-pack the container.

This was unfortunately not the case with this container:

CAP products were placed in the middle of other packages. Customs staff could only check and inspect the container after it had been partially unloaded.

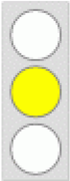


DO NOT "conceal" CAP products



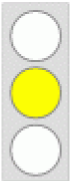
Additional work caused by searching for CAP products

4.2.6 Useful hints



Do not work in a too confined a space!

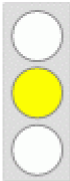
The area in which containers are packed should be spacious enough to prevent staff from obstructing each other. If too many cargo items are made available in a tight space and several fork-lift trucks are used, this can easily lead to a reduction in efficiency and damage to the goods.



Use lift trucks with lighting!

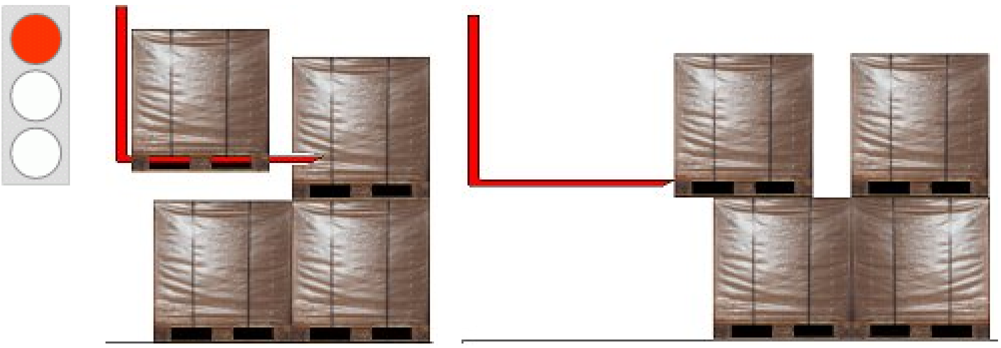
Quick changes from brightness to darkness are extremely demanding for fork-lift truck drivers' eyes. They can cause damage by bumping etc. before their eyes have adjusted to the darkness. Recommendation: Use lift trucks with adequate lighting!

When loading under tight space conditions, there is a risk of damage. In the case of bagged cargo, "bleeding" paper bags can endanger the stability of the entire block. To minimize the risk of damage, a helper should hold a sufficiently wide strip of hardboard vertically between the cargoes when the pallet is inserted.



Risk for bagged cargo pallets

Work on homogeneous cargo items should be carried out using attachments suited to the goods in question. With heterogeneous loads, attachments should only be used if the devices can be attached and detached very quickly. The drum clamp shown above is picked up and put down by inserting or removing the fork. It is quickly secured by two pins and released again by removing the pins. It is always more efficient to work with fork-lift trucks equipped with a fork adjustment device and whose forks can be moved laterally in parallel.



High-risk working methods

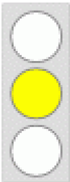
Packages are often mechanically ruptured by forks on loading and unloading as a result of carelessness, inexperience etc. If the forks are used to push a package into place, the forks can slip down and cause damage. This risk is particularly high if the equipment is in poor condition and the tips of the forks are not exactly parallel horizontally. If the forks are too long, goods stowed further behind are often also affected. Should damage of this kind remain unnoticed, it can pose risks to the environment and in the case of dangerous cargoes, cause substantial consequential losses and signify a violation of the law. As Section 4.2.7 of the CTU guidelines says:

> *Packages of dangerous cargoes should be examined and any found to be damaged, leaking or sifting should not be packed into a CTU.*

Damage caused during stacking or when pushing a load into place can effectively be prevented by using pieces of squared lumber of a suitable length and format, laid on and/or fastened to the rear of the forks.

High-risk working method

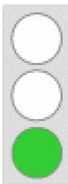
Packages should always be picked up resting fully on the fork and set down level. Loads should not be pushed with slightly raised fork tips. This could otherwise cause damage to the bottom of certain loads.

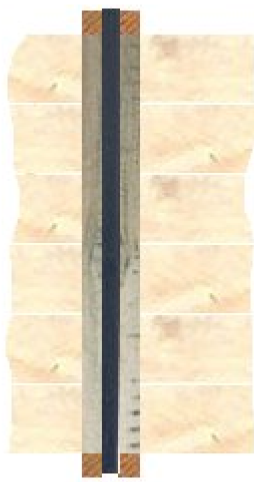


Faulty packaging

When handling long goods, the forks should be set as wide apart as possible from each other. Here, however, the packaging is the main concern. If long goods have to be pushed into containers, skids running in a longitudinal direction must be provided. Strapping must not run along the belt battens at the bottom. They must run along a milled groove.

Belt battens without a groove





Belt batten with a groove

If overstowage of the cargo items is an issue, the steel strapping should run in a groove at the top in the same way. An all-round groove is ideal. To prevent the strapping from tearing off, suitable hardboard strips can be placed under the belt battens with the smooth side facing down. This reduces friction, which in turn makes it easier to push loads in.

Correct arrangement of skids

Cases built like this are easy to push into containers provided they have been set down with the front end in the door area. This has not been done here. Loads should not be pushed over a ramp, since usually the metal sheets are textured or made of deck plate.

Inadequately packaged goods

Even the best packing company in the world cannot reasonably be expected to work well if the goods they are delivered are atrociously packed. Here, the load unit was destroyed by a braking maneuver of the fork-lift truck. Generally, only professionally prepared units should be loaded. Matters may be improved in the long term by inspection of incoming goods, good customer contact and regular quality control at the consignor end.

Inadmissible pushing

Pushing gently with a pallet as padding can be tolerated for certain goods in exceptional cases. It cannot be tolerated with goods which could be damaged by such actions.

There is a considerable risk of damage on unloading at the destination, if the packers do not have the stripping of the container in mind when loading it. Cargo must always be packed in such a way that the cargo transport units can be unloaded as easily as possible. This can also mean attaching belts, slings or similar to individual cargo items which can then be used to pull out the items. If, for instance, it would be difficult for recipients to attach slinging equipment to loads in open-top containers, the shipper should leave it in place and tie it together in such a way that it is immediately accessible from the top.

When working with lifting gear and single hoisting points, auxiliary ropes should be attached to the load or the hoisting equipment to be able to safely guide the cargo items.

4.2.7 On completion of packing

The CTU guidelines provide very detailed instructions on what action is to be taken after packing has been completed. Special instructions are given for cargo transport units with dangerous cargoes. Section 4.4.2 deals with the documentation. This states:

4.4.2.1 For transport by sea, regulation 5 of chapter VII of SOLAS 1974, as amended, requires that the person responsible for the packing of dangerous cargoes into a container or road vehicle shall provide a signed Container Packing Certificate or Vehicle Declaration stating that the cargo in the unit has been properly packed and secured and that all applicable transport requirements are met.

4.4.2.2 The IMDG Code recommends the following declaration:

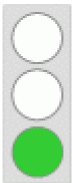
- *The container/vehicle was clean, dry and apparently fit to receive the cargoes.*
- *If the consignments include cargoes of class 1 other than division 1.4, the vehicle or freight container is structurally serviceable in conformity with Section 12 of the introduction to class 1 of the IMDG code.*
- *No incompatible cargoes have been packed into the vehicle or freight container (unless authorized by the competent authority concerned in accordance with 12.2.1 or 17.6.3.1 of the General Introduction to the IMDG code).*
- *All packages have been externally inspected for damage, leakage or sifting, and only sound packages have been packed.*
- *All packages have been properly packed into the vehicle or freight container and secured.*
- *Drums have been stowed in an upright position, unless otherwise authorized by the competent authority.*
- *The vehicle or freight container and the packages therein are properly marked, labelled and placarded.*
- *The dangerous goods declaration required in subsection 9.4 of the General Introduction to the IMDG code has been received for each dangerous cargoes consignment packed in the vehicle or freight container.*

4.4.2.3 A Container Packing Certificate/Vehicle Declaration is not required under the RID, ADR, ADN or ADNR regimes, even though they may be required for inland domestic transport in certain countries. However, such certificates will be needed if the transport operation includes sea voyages. They will then need to be provided prior to loading, as port authorities, berth operators and shipmasters may wish to sight them (or a copy) before accepting containers or vehicles packed with dangerous cargoes into their premises or aboard their ship.

In accordance with Section 8 of the GGVSee, manufacturers and distributors have special duties. Usually, they are referred to as the "shippers".

4.2.2 The shipper should also ensure that dangerous cargoes are packaged, packed, marked, labelled, placarded and provided with the required signs, in accordance with the applicable regulations. A declaration that this has been carried out is normally required. Such a declaration may be incorporated into or attached to the transport documents.

4.4.2.5 The functions of the dangerous goods declaration (see 4.2.2) and of the Container Packing Certificate/Vehicle Declaration may be incorporated into a single document; if not, these documents should be attached one to the other. If these functions are incorporated into a single document, e.g. a Dangerous Goods Declaration, shipping note, etc., the inclusion of a phrase such as "it is declared that the packing of the cargoes into the container/vehicle has been carried out in accordance with the provisions of section 17 of the General Introduction to the IMDG code" is sufficient. Where both declarations are included in a single document, separate signatures are required for the two declarations.



Container set down, closed and sealed correctly

3.3.3 After closing the doors, it should be ensured that all closures are properly engaged and secure. Usually a seal is applied to a container. Care should be taken that sealing procedures are carried out properly.

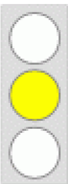


Correctly closed and sealed containers


Correctly closed roof on an open-top container

When using flatracks with a load covered with a tarpaulin, it must always be taken into consideration that the flats are transported on deck. The tarpaulins must therefore be secured against storms.


This tarpaulin would be torn in stormy weather.




Better but still not 100%

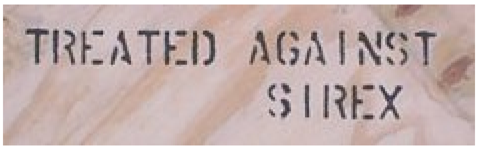

Tarpaulin secured against storms

Hinge mechanism on a collapsible flat

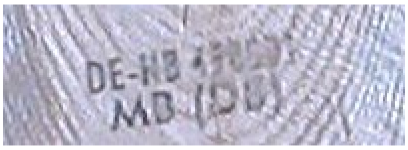
3.3.4 Where CTUs have hinged or detachable fittings, a check should be made that they are properly secured, with no loose equipment likely to cause a hazard during transport.

A check should additionally be performed on refrigerated containers to ensure that the correct refrigeration temperature has been set. Containers carrying dangerous cargoes must be provided with the relevant placards. For further information, see the sections on refrigerated containers and marking of containers with dangerous cargoes.

If a container is shipped to a country in which there are quarantine regulations regarding the treatment of wood, e.g. Australia, New Zealand and China, it must be ensured that all wood carried in the container conforms to these regulations. Either all parts must have previously been fumigated or heat-treated and marked appropriately, or the entire container must be subjected to special treatment. A copy of the wood treatment certificate must always accompany the container. This should be stored directly inside the right-hand container door or in a weather-resistant pouch on the outside of the door.



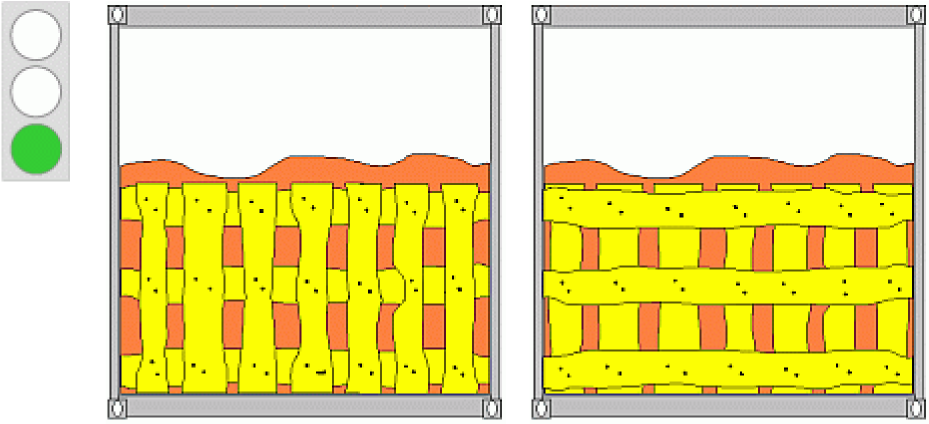
Notice on a plywood case



Fumigation stamp on a wooden wedge

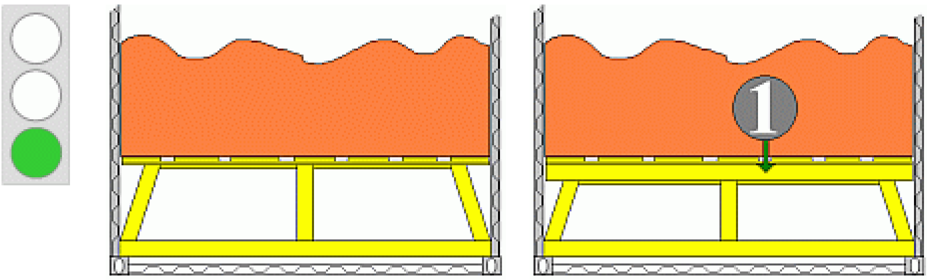
4.2.8 Final work in the door area

The requirements laid down in the CTU guidelines with respect to a secure load face in the door area can be met in a number of different ways. One option is to place a wooden lattice or pallets against the last portion of the load and to brace these against the rear corner posts:



Lattice used to secure the face of a load

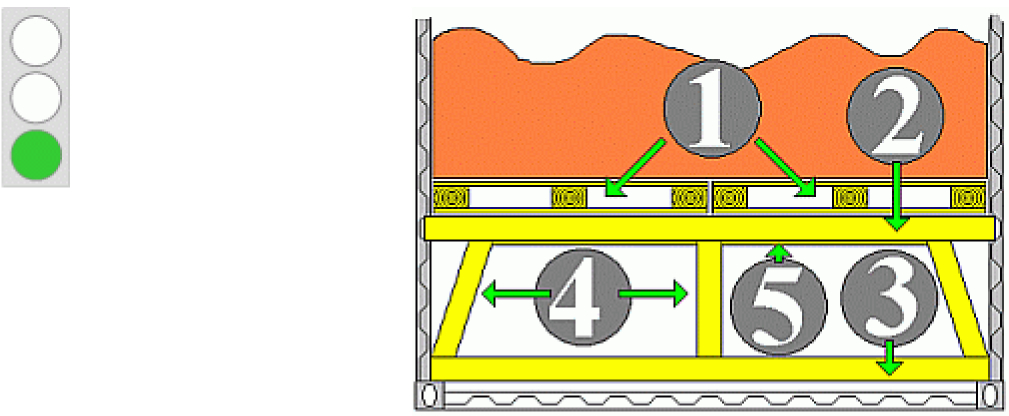
Lattices can also made by nailing inexpensive, untrimmed wooden dunnage boards together. How lattices are to be placed in front of the load depends on the forces which have to be absorbed and what type of load it is. In the case of stacked, palletized goods which are firmly secured to the pallet, the variation shown on the right is suitable. Then, the horizontal boards in contact with the load should cover the lower area, the seams of the stack and the upper area. In the case of goods stacked in three layers, lattices must therefore be made of four horizontal boards.



Bracing gaps in the door area of containers

If the mass to be braced is not too large, the bracing can be placed directly against the lattice (left figure). If forces from larger masses are to be absorbed, an additional cross piece (1) must be fitted.

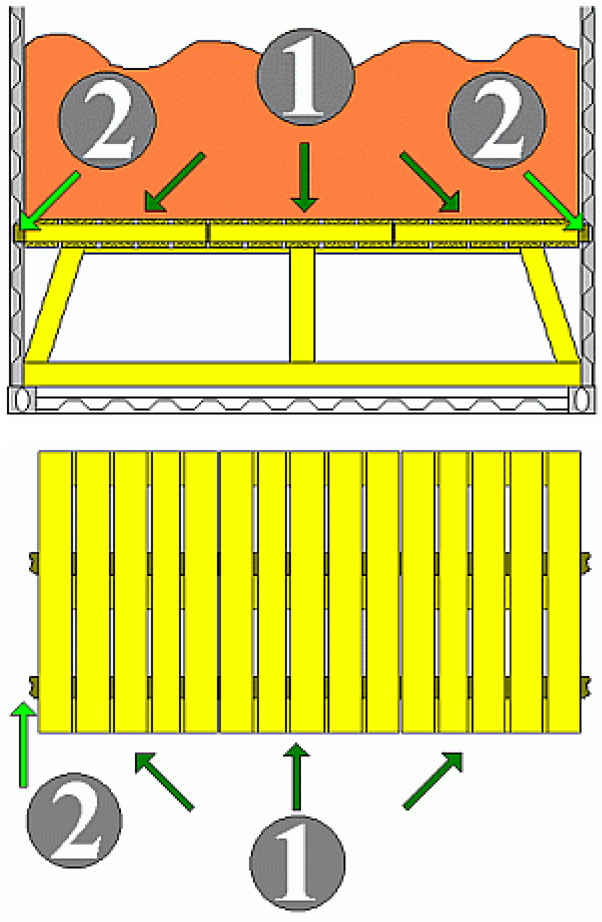
If pallets suitable for use with containers are available, for instance with the dimensions 1,150 mm x 1,550 mm or 750 mm x 1,150 mm, they can also be used instead of a lattice:



Bracing with pallets designed for container use

Key: (1) Two pallets with the long edge placed transversely;
(2) Squared lumber fitted in the corrugations; (3) Cross pieces fitted in the door area; (4) Squared lumber bracing; (5) Locking battens to prevent the diagonal stays from sliding together.

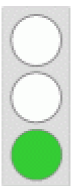
If three pallets are arranged with the narrow edge running transversely, squared lumber can be inserted between the pallet boards.

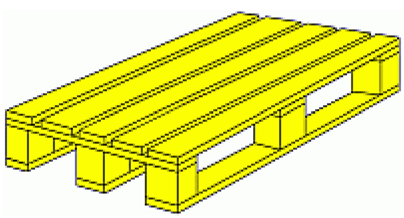


Securing by inserting squared lumber inside pallets

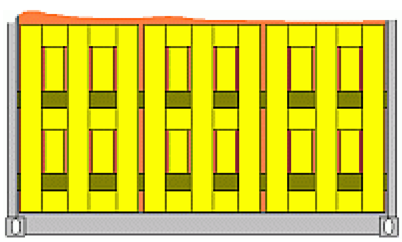
Key: (1) Three pallets arranged vertically
- with the narrow edge positioned transversely;
(2) Squared lumber inserted between the pallet boarding.

If double deck pallets are not used, but four-way pallets are used instead, for instance, the completely boarded side should face the load:



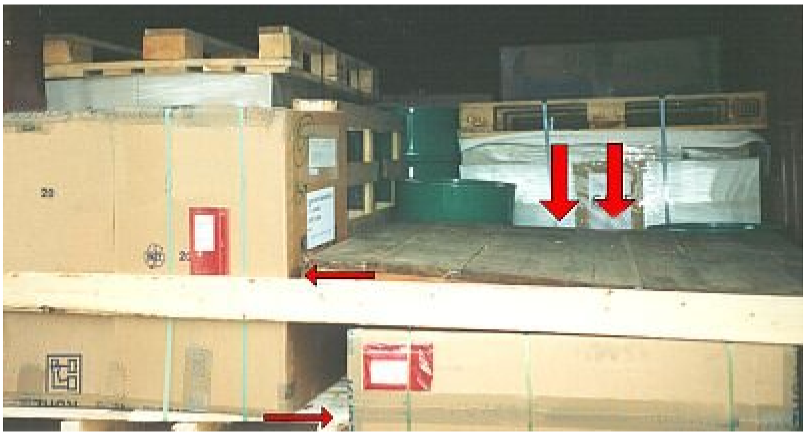


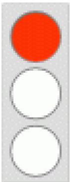
Four-way pallet



Arrangement of pallets

Unsatisfactory packaging results in errors in load securing which could only have been prevented by additional outlay of material and work. The visible stowage gaps must be filled in any case:

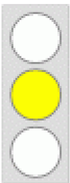


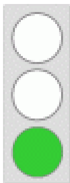

Stowage gaps between drums and other packages

This picture clearly illustrates points where harmful load forces can arise.

The CTU guidelines require that when during the final stages of packing a CTU, care should be taken so far as is practicable, to build a secure face of the cargo. This is to prevent cargo from falling out when the doors are opened. A board fitted between the corrugations is not capable of ensuring this.

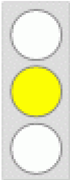
In order to come anywhere near fulfilling this requirement, it would have been necessary to have fitted a number of transverse boards or - better still - a lattice made of several boards:

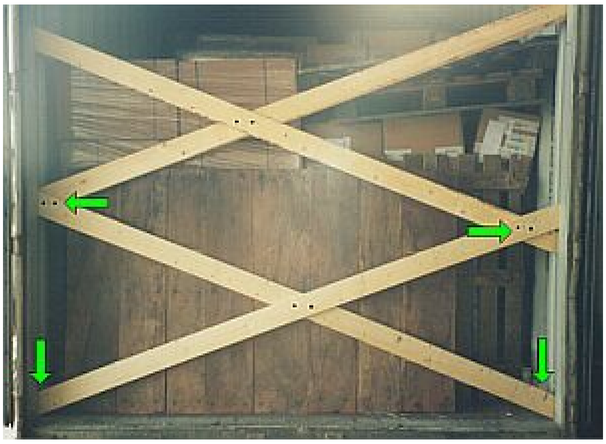





It can be assumed that if the loads are otherwise correctly stowed, the boards or lattices will be held in place by the container doors, preventing any longitudinal shifting of the load. Since dynamic forces are no longer acting on the load when the container is opened, it is not to be expected that cargo items will be able to fall out when the doors are opened. In this way, the requirements of the CTU guidelines for a secure load face can be met.

A similar situation can be expected for the following container, although the securing forces of the diagonally fitted boards are not ideal:





Securing the face of a load with diagonally fitted boards

It is important that the boards are placed and nailed to each other in such a way that their position in relation to each other and to the container cannot change.

What is also unacceptable about this container is the quantity of old pallets which have been used and the carelessness of the packing.

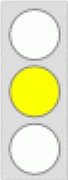
The issues are completely different when gaps remain in the door area on partly loaded containers. Such primitive securing is in no way adequate here - whether boards or squared lumber are used:

Inadequately secured face of a load

At (1), the squared lumber could slip down and then become loose. This "securing", already primitive enough, would then become ineffective. The usual error made in packing, namely leaving loading gaps, is also to be seen in this container (2).

Securing with squared lumber by bracing it against the corner posts of the container, is relatively quick and not excessively costly. Since the case (1) protrudes slightly out of the face of the load, no optimum solution is possible

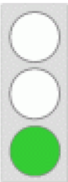
here.

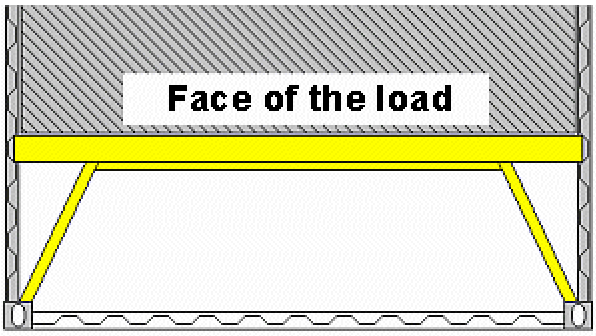


Securing by bracing against the corner posts

If the load is not braced against the corner posts, the wood fitted horizontally between the corrugations cannot hold the face of the load securely. This can result in damage to the container corrugations if the forces from the load become too high and the squared lumber is pressed toward the door. Fitting squared lumber and boards in the container corrugations is a very easy method of securing, but this method should be used on its own only for very light loads. In all other cases, boards and squared lumber must be fitted horizontally, supported against slipping down and also braced along the length of the container.

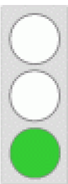
With the previous method, the transversely fitted squared lumber is subjected to bending stress across its whole width. The wood inserted at the container wall only has very little to "get its teeth into" on the corner posts. Securing material must therefore cover a large area and where possible be placed obliquely against the corner posts to ensure a high load-bearing capacity:



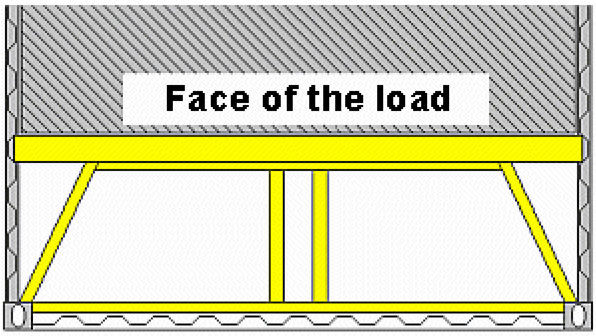


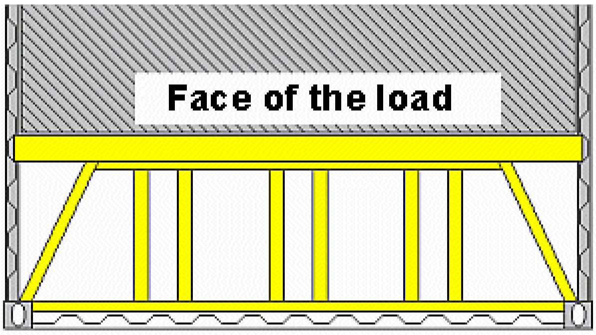
Bracing against the corner posts with medium-heavy goods - Top view

If the total weight of the load in the container is heavy or extremely heavy, additional squared lumber bracing against the doors must be provided.



Bracing against the corner posts with heavy goods - Top view



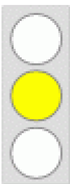


**Bracing against the corner posts with very heavy goods
- Top view**

Inadequately packed container section

It is constantly forgotten that during transport, the vehicle is subject to changes in speed and direction. The inertia forces resulting from these changes set the load in motion relative to the vehicle.

Securing of the face of the load in the door area of this container is inadequate and needs to be improved in several ways:



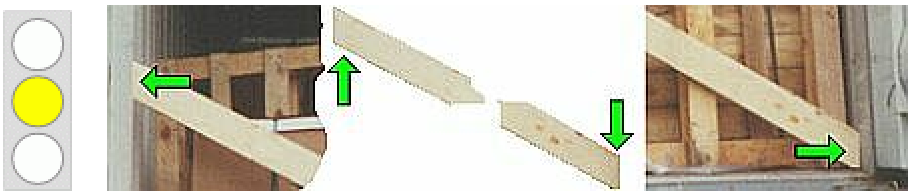
Incorrectly loaded container with dangerous goods

Dangerous cargoes were loaded in this container. But not - as the regulations demand - in the door area; instead they were "concealed" within the rest of the load. See Section 4.3.7 of the CTU guidelines for the relevant regulation. This states that "dangerous cargoes consignments which form only a part of the load of a CTU should, wherever possible, be packed adjacent to the doors with markings and labels visible."

Attention has already been drawn to the special measures required for securing cargo by the doors of a unit several times. It is dubious whether the two crossed boards can actually prevent the load from falling out if the container has traveled for some distance. This is partly because the boards were not beveled:

No beveling on the ends of the boards

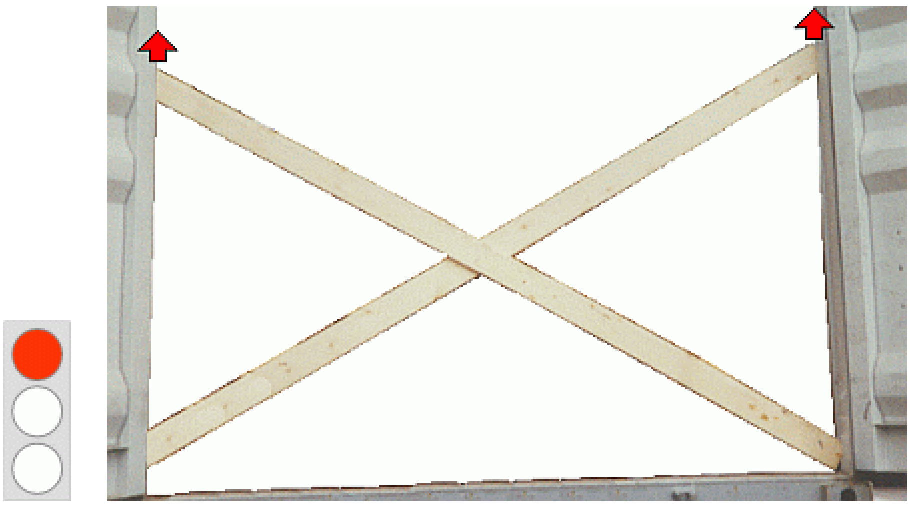
The fitted board does not have enough "to get its teeth into" in the groove of the container corrugations to withstand the potential loads.



Improved grip by beveling the ends of the board

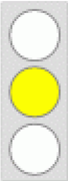
Beveled boards can withstand loads acting toward the door much better.

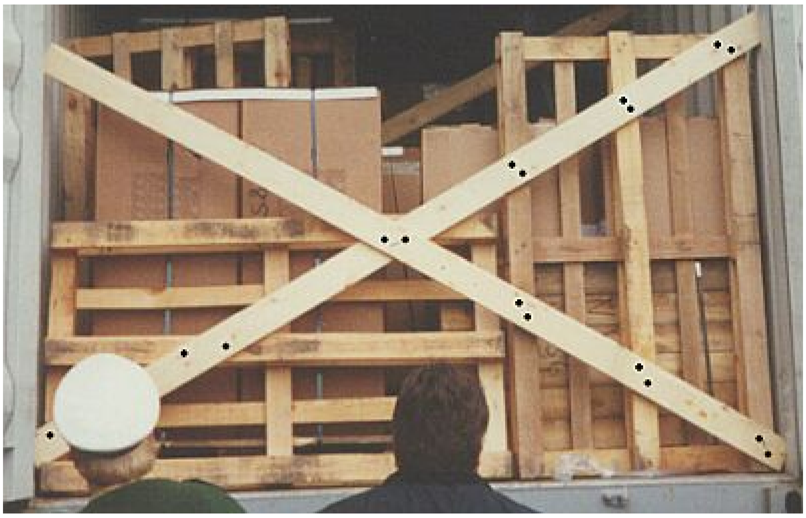
A weak point of all securing measures of this kind, however, is that the boards slip away toward the top and then no longer provide any protection.



Diagonally inserted boards can escape upward

Theoretically, one viable solution to this would be to brace the boards toward the top, but it would be difficult or awkward to achieve this in practice.





It is not always possible to secure boards by nailing

It is not always possible to secure diagonally inserted boards by nailing. This type of securing method should therefore be avoided entirely. Horizontally fitted boards or lattices are suitable for relatively light loads. Squared lumber or other lumber measuring 5 cm x 8 cm is a better solution for medium heavy goods. Professional bracing must be built for heavier loads.

4.3 Load securing

A lot of material has been published about load securing in the last few years. The necessity for correct load securing has been unanimously confirmed by experts. However, the most effective methods are subject to fierce discussion. New regulations have been introduced and old regulations have been reworked. A range of recommendations and handbooks have appeared on the market designed to help the user, but these books do not always live up to expectations.

When selecting load securing methods and using load securing materials, economic considerations should obviously play a significant role, but safety should never be compromised as a result.

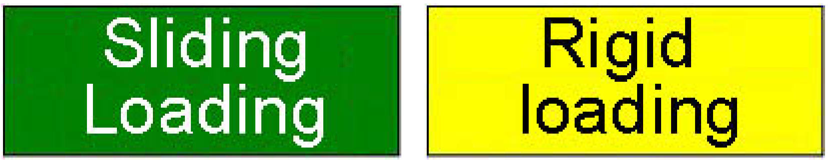
This part of the Handbook is designed to provide the user with information, particularly with regard to the practical techniques of load securing. But at the same time, as far as this is possible, the background and context will also be discussed from the theoretical point of view. It is impossible to do full justice to this topic given the limited number of pages available. However, the author hopes that this work will offer a suitable introduction to this topic.

4.3.1 General load securing methods

Because Cargo Transport Units (CTUs) are carried on all types of transport vehicle we shall here introduce some specific terms for loading and securing methods as used by each industry. Almost all fields of shipping refer to load securing in one way or another, yet each field has its own specialist terms. § 2 of the German rail traffic regulations (EVO) defines a general obligation to secure loads. This states:

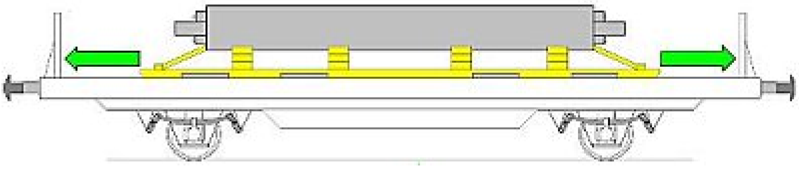
> *EVO - § 2 - Stowage*
> *The objects to be loaded must be fundamentally safe and secure and should not be able to move as a result of jolts or vibrations that can be expected under normal operating conditions. The possibility of longitudinal movement is permitted insofar as the magnitude of this movement is limited by the use of appropriate means and there is no risk posed to safety.*

This paragraph provides an important piece of information, namely that rail transport permits two fundamentally different securing methods:

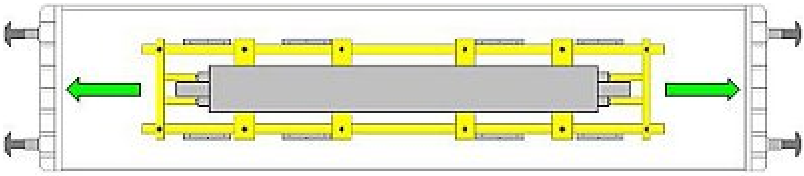


The **sliding loading method** allows cargo to move in the direction of impact as a result of the jolting forces that occur during rail transportation. With this method, jolting energy is absorbed by friction work. The magnitude of deceleration in g (1 g = 9.81 m/s²) corresponds to the size of the friction coefficient between the package and the loading surface. The lower the friction coefficient, the lower the forces acting on the cargo, but the greater the travel and vice versa. As a result of the limited travel which is possible, this method is geared toward the friction between wood and wood with travel of at least 1.5 m on each side of the object. If the possible travel is less than 1.5 m, then the use of non-slip materials placed between the load and the floor of the freight car is required.

The German railroad authorities recommend the use of this method for sensitive loads, for example, machines etc. if the properties of the load and the length of the loading area permits the method and if the goods are not in danger of tipping. The lower end edges of the load should be beveled in order to ensure that they do not snag on uneven areas of the freight car floor. If the bottom surface of the goods does not allow them to slide, they should be firmly attached wooden skids or sleds. The leading edges of the skids should be shaped like runners.



The sliding loading method - Side view



The sliding loading method - Plan view

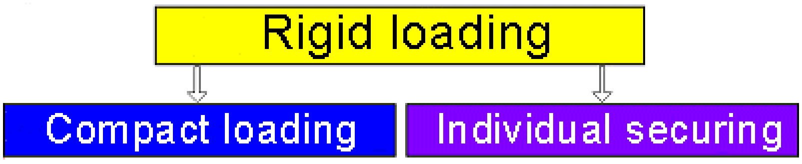
The loads must be secured against sideways movement. Squared wooden guide rails attached next to the loaded goods or sleds in such a way that the load not prevented from sliding have proved themselves in practice.

Any movement by the load must not cause permitted axle loads to be exceeded. Thus, the maximum permissible load of the freight car cannot be fully exploited. The axle load must not exceed the value that results when the sum of the tare weight plus the permitted maximum load is divided by the number of axles or bogies. The ratio of the axle loads of cars with two axles must not exceed 2:1, that of bogie cars must not exceed 3:1.

If the floor surface is of the same nature, goods will slide the same distance, regardless of their mass. Thus a number of partial loads or load groups consolidated as blocks can be loaded on a car using the sliding loading method. The loading guidelines require a gap of 50 cm between the individual goods/groups. When using this type of loading, several consecutive jolts during switching should not occur in the same direction. Cars loaded in this manner are specially checked at the switching yards.

Warning: The sliding load method may only be used in a Cargo Transport Unit if you can be absolutely sure that the unit will be transported exclusively by rail. The sliding load method should never be used with any other means of transport.

The term **rigid loading** comes from the loading guidelines published by the UIC (International Rail Union) and is used as a blanket term to cover both compact loading and individual securing.



The term "rigid loading" means exactly what it says: the load must be secured on or in a cargo transport unit in such a way that it is unable to move. If this demand is met, the load is unable to topple, fall down or become damaged/cause damage in any way. However, the term does not specify the method of securing that is to be used.

Compact loading

The term "compact loading" also clearly indicates the concept. A compact load is one which is stowed without gaps or, insofar as gaps remain, where these gaps have been filled by resilient material.

The term also immediately suggests that the CTUs must have borders of sufficient load bearing capacity around the loading area in order to allow a compact unit to be formed in which nothing is able to move. Even this simple description makes it clear that a CTU that does not have fixed side or end walls is not suitable/only partially suitable for securing loads in this way.

Individual securing

Individually secured loads are attached to the transport unit using special load securing aids. The term does not, however, indicate exactly how securing is to take place. It does however, imply that certain components must be available or certain requirements must be in met in order to allow loads to be secured individually: These components may be lashing points or other securing mechanisms on either the transport unit itself or the load.

Aim of load securing mechanisms

Securing against sliding | Securing against tilting

If these load securing measures are carried out correctly, both of the important requirements of load securing will have been met: The load is unable to slide or tip. If we go into more detail, tipping can fall into two categories.

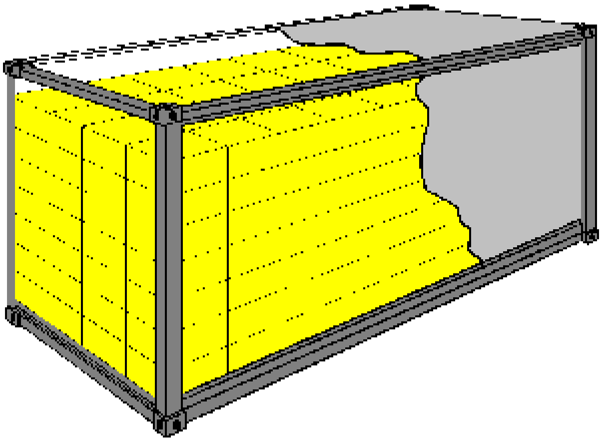
Securing against tilting

Securing against tilting | Securing against tipping over

There's still time to ask for information.

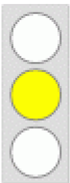
4.3.2 Achieving a tight fit using container components and special components

This type of tight-fit is designed to transfer the forces from an item either directly to components of the transport unit, such as the walls or stanchions or directly via parts of the load which are capable of withstanding these forces. This cost-effective method of load securing has already been referred to as compact loading. If the packages have the right shape, size, strength and compatibility they can be packed together in tight contact. This forms a coherent loading block. If this block is unable to move in any direction, then no further securing measures will be required.



Compact loading in a box container

This method of packing may also be described as a complete longitudinal and transverse block. All the inertia forces acting on the load are transferred directly by the load to the components of the means of transport. The prerequisite is that the components of the transport unit are capable of withstanding such forces long-term.



A virtually complete compact load of cases in a container

Goods can often be packed successfully against the end walls and the sides. If the packages do not fill the entire length of the container, appropriate securing mechanisms should be used in the door area. If there is a risk of the packages working loose from the block as a result of the movement of the ship, then additional lumber bracing or other similar securing mechanisms should also be applied on top of the load.

Tight-fit for special receptacles traveling on a special flatrack

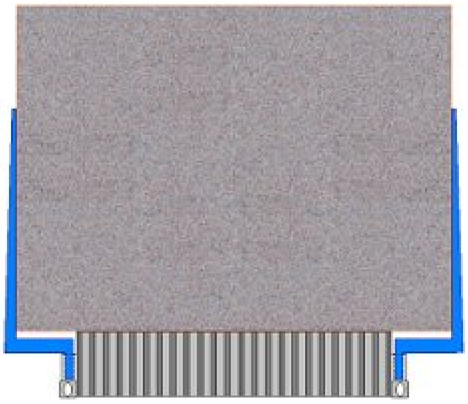
The half height open top containers in situ, as seen from the end

The flatracks shown here were specially designed to accommodate stacked receptacles. They are used to deliver securing elements such as stacking cones, twist locks, bridge fittings and other similar items used for securing containers on board ships. Solutions of this type are also suitable for transporting other small items. Taking into account the costs of packing and securing items, the use of a more expensive special container may, in the long run, actually pay for itself, particularly as the half-height saves on transport volume.

Platform containers of normal construction can usually be loaded in a compact/tight-fit fashion if the dimensions of the load are identical to the dimensions of the container loading area:

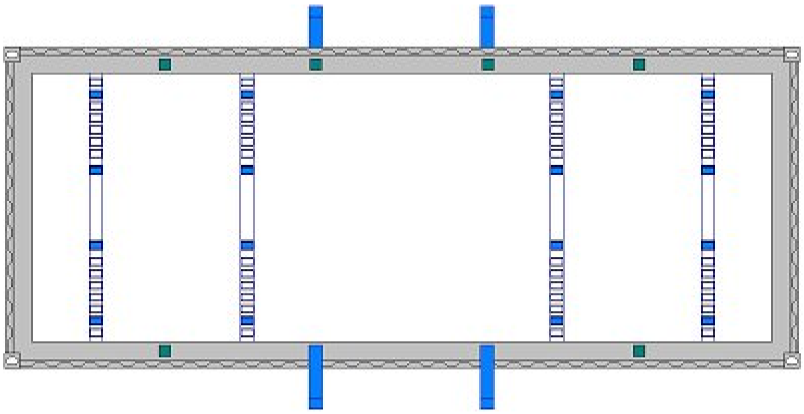
Compact stowage of a case on a flatrack with stanchions

This constellation is very rarely seen in practice. Shortcuts are not permitted in the field of load securing, but if the intended dimensions of a case are very close to those of the loading area of a real flatrack then it is possible to make the case fit the flatrack by building it slightly larger than originally planned. The additional costs invested in building the case are recouped by the costs saved on securing the case, and the risks of carriage are also lower.

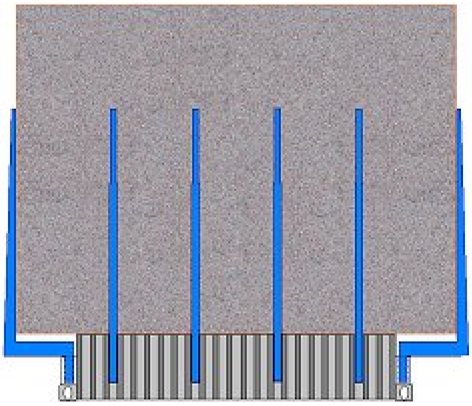


Compact tight-fit securing of a power substation using specially shaped stanchions crosswise on a flatrack

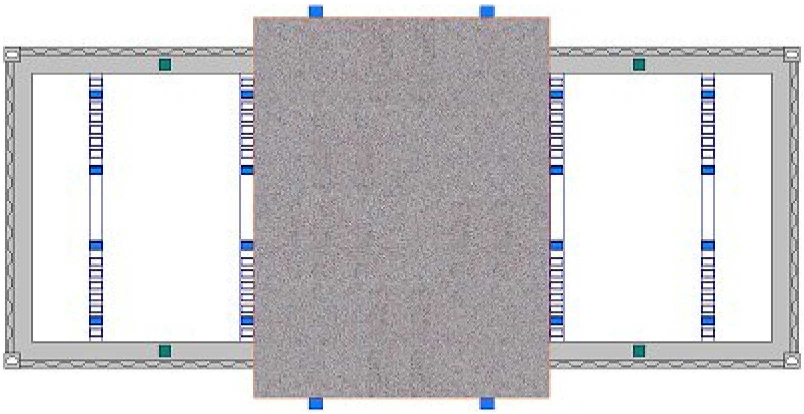
The load shown here is a substation. An overwidth such as this would normally require a considerable load securing outlay. The adjustable stanchions shown in blue (and which must be specially manufactured) can be used to ensure an excellent lateral tight fit. In reality, cargo items are not so large that they reach as far as the end walls. In this case, therefore, they would need to be braced with wooden beams or similar material. Securing by lashing would be even more work-intensive. Even if the items to be sent were the same length as the container, the overwidth would prevent the cargo from being loaded hard up against the end walls since the container would no longer fit into the slots of the ship. A possible solution would be to use a flatrack with special stanchion pockets that allow the load to be secured as a tight-fit.



Stanchion pockets on a specially designed flatrack



Power substation secured using removable stanchions and adjustable stanchions - Side view

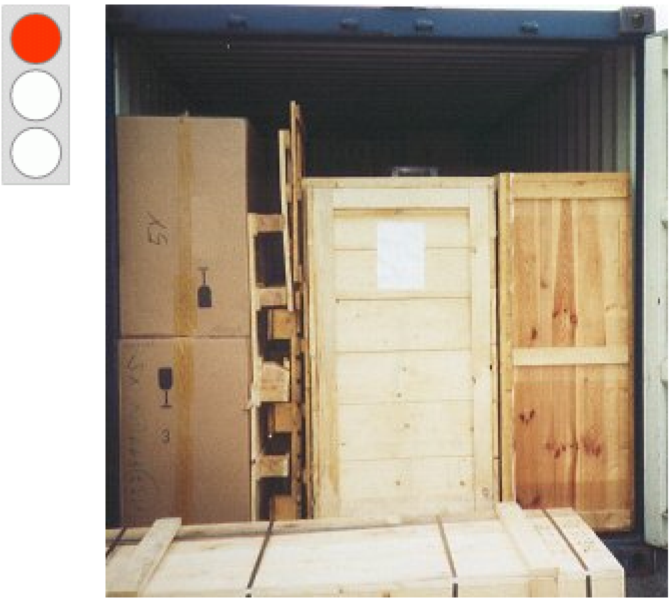


Power substation secured using removable stanchions and adjustable stanchions - Top view

The means of transport are often only partially filled. Gaps may arise as a result of the characteristics of the load or for packing reasons. If so, then the load must be secured using the appropriate methods. Special securing measures may be required if there are edges on the means of transport or the edges available are not able to bear the load, as is the case when using partially open/open means of transport. In these cases, other methods will need to be used. These are described in the following sections.

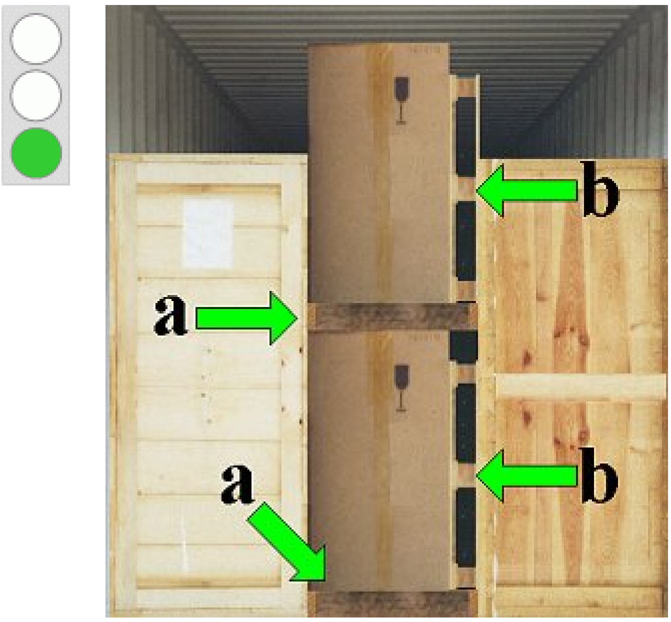
4.3.3 Achieving a tight fit by filling in gaps

This method of compact loading involves leaving gaps that must be filled in. When using box containers, these gaps may be longitudinal or transverse and should be filled in appropriately unless there is a better way of securing the cargo. Filling is usually the better and more economical method since lashing inside box containers requires considerable effort. The situation with platform containers is different; here lashing is often more suitable. Objects suitable for filling in gaps are wooden battens, which will be discussed in the next section, paperboard which can be used for very small gaps, boards and individual pieces of squared lumber for small gaps and pallets for larger gaps. If smooth surfaces are available or measures can be taken to eliminate sharp edges, then airbags may also be used.



Incorrect securing by filling

Compact packing and filling of gaps can only be implemented effectively if all parts of the load are sufficiently robust. Here, for example, the movement of the ship and the container while at sea would, sooner or later, destroy the cartons that are marked fragile. The gaps that occur as a result of this would then put the wooden cases at risk. The fact that the upper of the two cartons has been loaded upside down is not particularly good, but it is also not forbidden. If the shipper wishes to ensure that a packaged item is transported upright, it must be marked accordingly.



Correct filling of spaces

The gap has been left between the two strong wooden cases and filled in using boards and squared lumber (a). The cartons were loaded into this space. The remaining spaces were filled in using old pallets (b). The forces acting on the wooden cases are transferred from case to case by the squared lumber and onto the side walls of the container. The pallets are simply transferring the forces from the cartons to the case on the right.

An important note referring to the use of "old materials" is given in section 3.2.12 of the CTU guidelines.

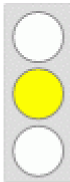
> *When deciding on packaging and cargo-securing material, it should be borne in mind that some countries enforce a garbage- and litter-avoidance policy. This may lead to limitations on the use of certain materials and imply fees for the recovery of packaging at the reception point as well as similar problems for the shipper of the cargo. In such cases, reusable packaging and securing material should be used. Increasingly, countries are requiring timber dunnage and packaging materials to be debarked.*

According to Section 8 of the GGVSee "shipper" is understood to mean the manufacturer or distributor.

Filling a space in the vicinity of the door

The space remaining in the vicinity of the door is filled in using upended pallets placed across the space and squared lumber beams fitted into the corrugations of the container. Care must be taken if the overall mass of the load is large, since the use of this method could cause damage to the corrugations.

If possible, the load should be braced against the door posts in the vicinity of the doors. If this is not possible, the door area can be filled in, but in such a way that the load is spread over a sufficient area that no harmful pressure points arise.



Corrugations run the risk of being damaged

Filling in space left in the middle of a container

Leaving spaces in the middle of a container and filling them in requires the packer to calculate the required dimensions exactly. With good planning this is not a problem. There is an advantage to this, since it allows the distribution of weight to be better organized.

Using airbags to fill in a space left in the middle of a container

Since airbags should not be used in the vicinity of the door for safety reasons, the obvious option is to leave space in the middle of the container. The airbags can be affixed and partially inflated before loading the cases in the door area. Once the cases have been put into place, the left-hand door is closed and the airbags can be inflated fully.

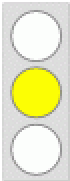
Impractical method of filling a gap in the middle of a container using airbags

Theoretically it is possible to determine the size of the gap and to fully inflate the airbags before loading the boxes. However, this runs the risk of the airbags being crushed without the packers being able to monitor this, since the height of the cases means that the airbags are no longer accessible. This method of securing is practical when used with containers which have side doors and with platform containers which can be accessed from the side.

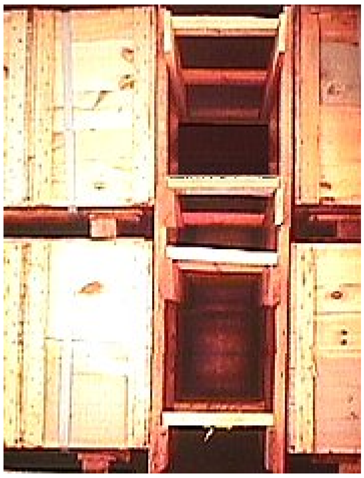
4.3.4 Achieving a tight fit by bracing

Bracing elements made of wood are a tried and tested method of load securing when packing containers. Squared lumber, battens and other elements are fitted in in such a way that spaces within the load are bridged. Bracing between the cargo and the container, and between the items of cargo are both commonly used methods. The latter is the more cost-effective solution since the required securing forces are generally lower.

Wooden bracing elements used to fill in gaps or empty spaces can often be made quickly and simply. Occasionally, however, they are feats of craftsmanship that require a great deal of experience and ability.



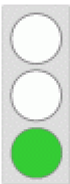
Horizontally bracing, poorly placed in part

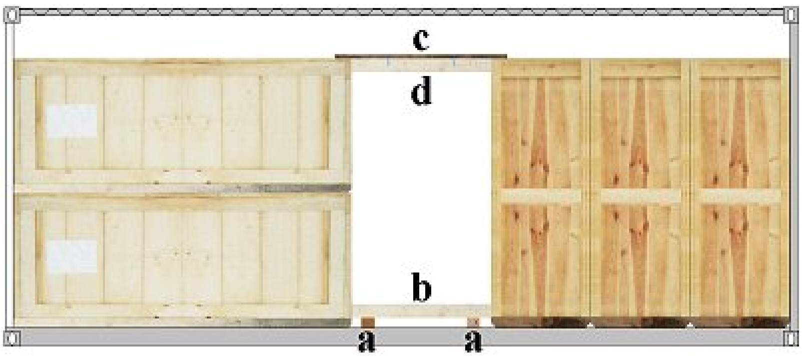


Well placed horizontal bracing elements

The important issue when bracing is that the forces must be transferred to the load-bearing components of the cargo transport unit or the packaged items that surround the gap. From a technical point of view, the bracing elements in both examples are equally well made. Horizontal elements are nailed onto vertical elements. The bracing elements are formed by the wooden beams that are cut to fit and placed transversely on top. The majority of this work can be done in advance outside the CTU. Only the bracing must be put in place inside the container. The advantage of the method shown on the right is that the bracing elements are placed level with the strongest parts of the cases, namely the top and the bottom.

This form of bracing (see the next figure) assumes that the packages either side of the gap are of almost identical height. Two transverse lengths of squared lumber are placed on the floor at the bottom of the space (a); depending on the forces that can be expected, at least two or more pieces of lumber are cut to fit and placed horizontally (b). Outside the transport unit, boards are prepared (c) which can then be nailed to the fitted lumber beams (d). This prepared bracing element is then lowered into place from above. All elements are stapled in place to prevent them from moving or are cross-braced with wooden boards.





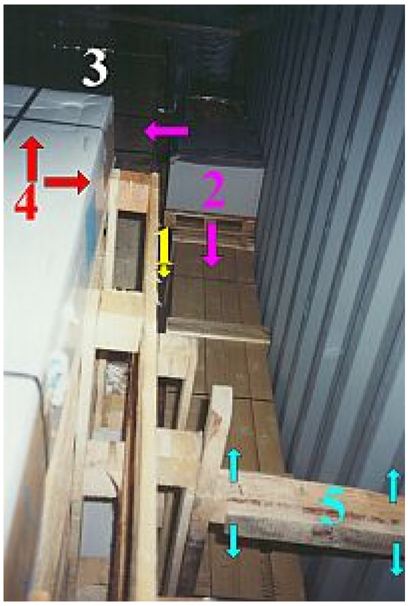
Tight-fit using a very simply made form of bracing

Using squared lumber fitted into a space in the way shown above is only possible if the packaged items are able to withstand such point loading. If the cases are not strong enough to allow the ends of the bracing beams to be placed against them directly, boards (e), planking or squared lumber can be additionally used to distribute the load forces. If this is not sufficient, vertical bracing elements or other methods of bracing should be used. The section on wood contains a number of other useful tips, as well as rules of thumb for calculating strength. Additional tips can also be found in the examples.

Bracing an overheight case on a 40' flatrack

The traffic lights here are on amber. There are a number of things to bear in mind with regard to the woodwork and the lashing that have been used here. This picture is only designed to indicate the wide range of bracing methods that can be used to create a tight fit.

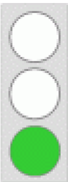
It is often the case that insufficient attention is paid to the bracing of gaps and/or the work is carried out in an unprofessional manner:

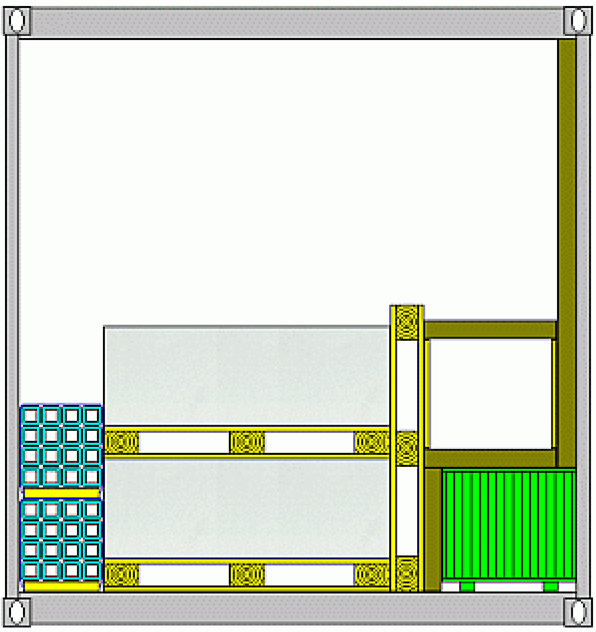


Badly braced spaces in a container

Space 1 allows the packaged items to slide around on the floor. Package 2 can slide both in the direction of the door and in the direction of the space. Package 4 can move forward into space 3 or escape to the side. Bracing element 5 is able to shift upward and downward on the right, and as a result of point loading may even damage the wall of the container. On the left, the bracing is able to move in all directions because it has not been fixed into place.

Neat packing and the professional use of beams and boards enables the remaining gaps to be braced without subjecting parts of the load or the container walls to point load forces.





An example of professional bracing

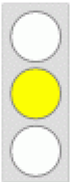
The picture shown here is of a stuffed container destined for an international voyage carrying, among other things, dangerous goods. In accordance with legal requirements a signed container packing certificate was available which testified that the container had been correctly packed and that the load had been secured adequately. It is difficult to believe that anyone could possibly issue this certificate for the load shown here.

The provisional bracing of the gap with a pallet (1) is not sufficient.

Goods are put at risk by provisional filling using a pallet

The red arrow (3) shows the foot of the pallet putting pressure on the wall of the drum. The cartons are not strong enough to ensure that they will survive without damage. The green arrow (4) shows where forces can be transmitted via the corrugations of the drum.

In order to ensure an even distribution of forces, walking boards, chipboard or hardboard (2) are required in addition to the pallet (1).



Filling in a space using a pallet and plywood

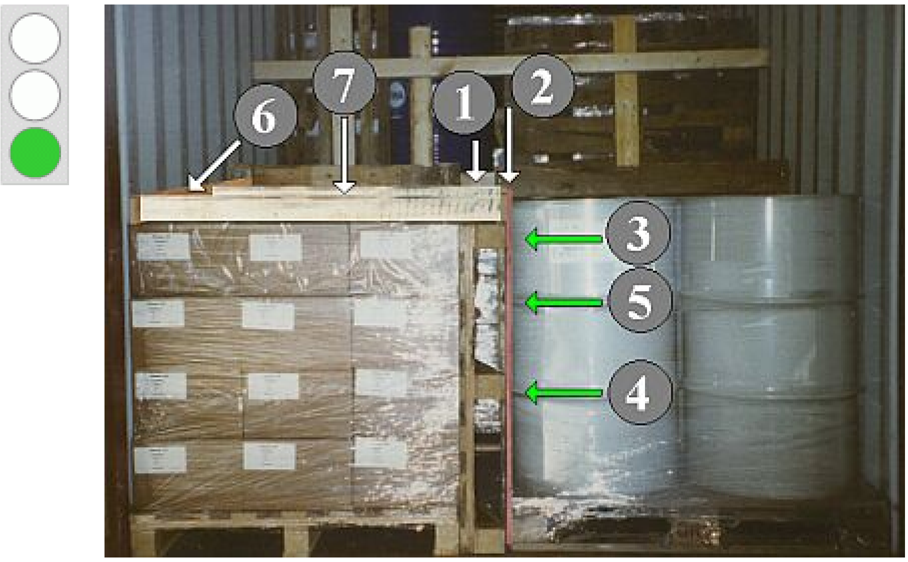
Key: (1) = Pallet placed vertically;
(2) = Plywood board placed vertically;
(3) Transmission of forces to the drum;
(4) and (5) = Transmission of forces at the corrugations of the drum.

This alone is not sufficient to provide 100% protection from damage. An important factor is that the forces from the drums are absorbed at the top of the boxes.

This can be achieved by laying pallets on top of the cartons in conjunction with squared lumber or using a simple construction made of squared lumber and boards. The latter can be prepared outside the container and then put into place.

Different bracing elements

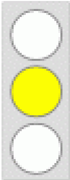
The option of boards (6) plus squared lumber (7) was used for the load shown here, which meant that the forces were transmitted to the top rims of the drums.



Absorbing the forces at the top of the goods in cartons

Every space in the load represents an increased risk of danger. Spaces should therefore always be filled in.

Badly wrapped pallets and spaces in the load



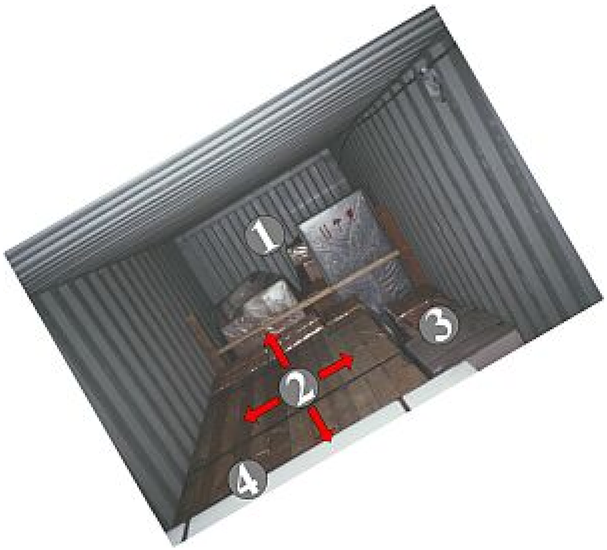
Filling in spaces in the load using two pallets

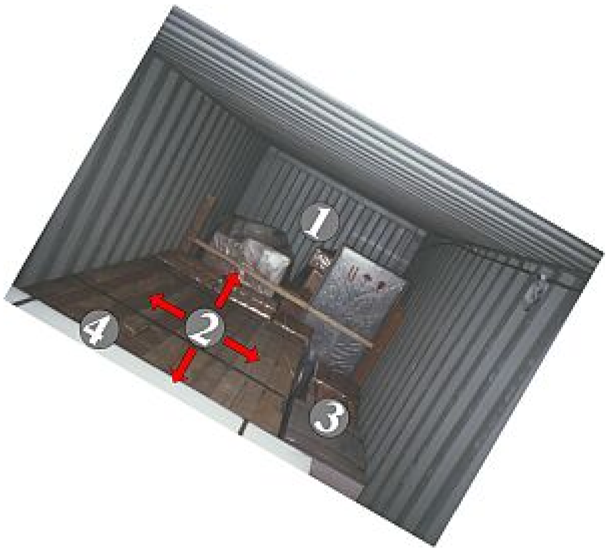
With goods that are liable to topple or palletized goods, as in (1) and (2), that are badly bonded to the pallet, it is not only the floor region which must be filled out, but a greater surface area as shown in the picture on the right where two pallets have been used for this purpose (3).

At a first glance, the container looks relatively well packed:

Faults in a container packed for export

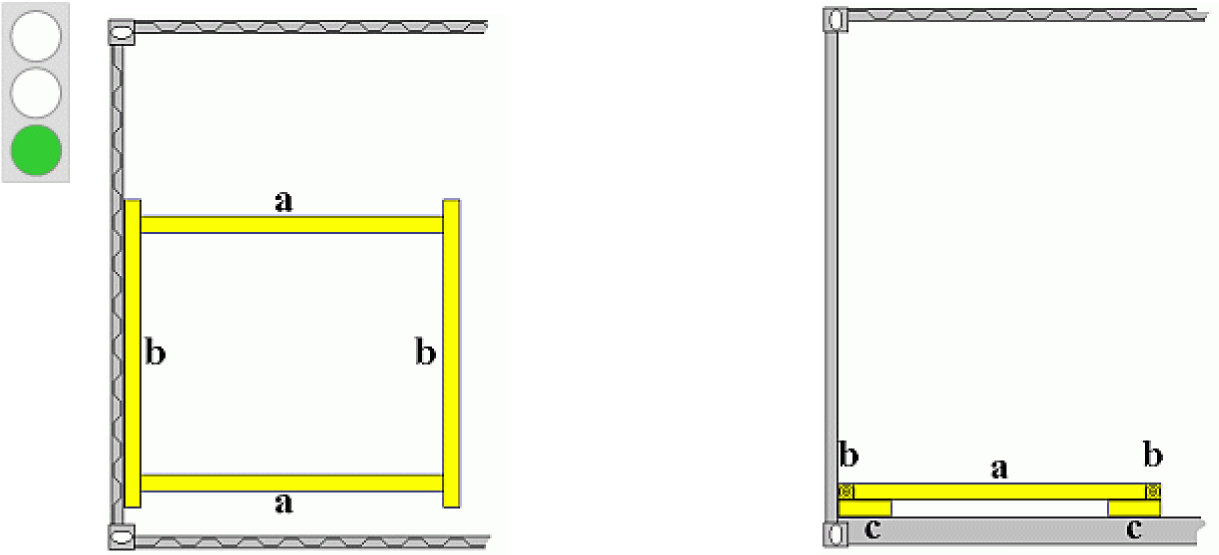
The heavy case has not been braced at floor level. The forces from the case are able to work in all horizontal directions. Depending on the method of transportation and the forces that occur as a result, the cartons at the front (1), side (3) or rear (4) can be damaged by the case (2) or may even be crushed completely.





Here a roll angle of 30° is shown. Such transverse forces occur when a container is transported on a ship in the usual fashion, namely with fore and aft stowage. To put the risks in perspective, it can be assumed that on a long voyage a container will be subjected to several tens of thousands of these roll oscillations. During pre- and post-carriage by rail or by road, the objects in front of or behind the case are the ones most at risk. The same would apply if the container was to be stowed athwartships on the vessel.

The possibility of the packages being crushed could have been avoided by using squared lumber in the floor region between the case and the sides of the container.



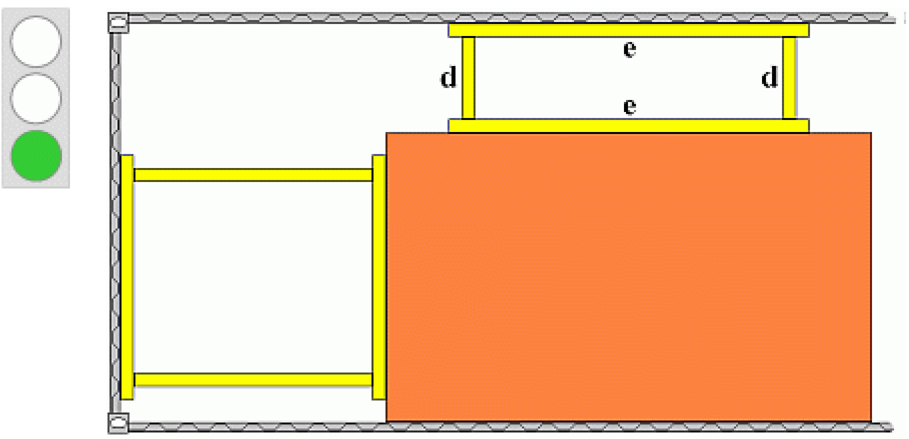
View from the top **View from the side**

Frame used to brace a case against the end wall of the container

The squared lumber beams (a) lying lengthways are designed to brace the case which has yet to be loaded. They are raised (c) in such a way that the case is braced at the level of the bottom of the case. Squared lumber or boards are placed at the end wall of the container and the front end of the case; these serve to distribute the load forces (b).

The cartons and pallets of batch (1) are then loaded into this section of the container and secured appropriately above the height of the case that is still to be loaded.

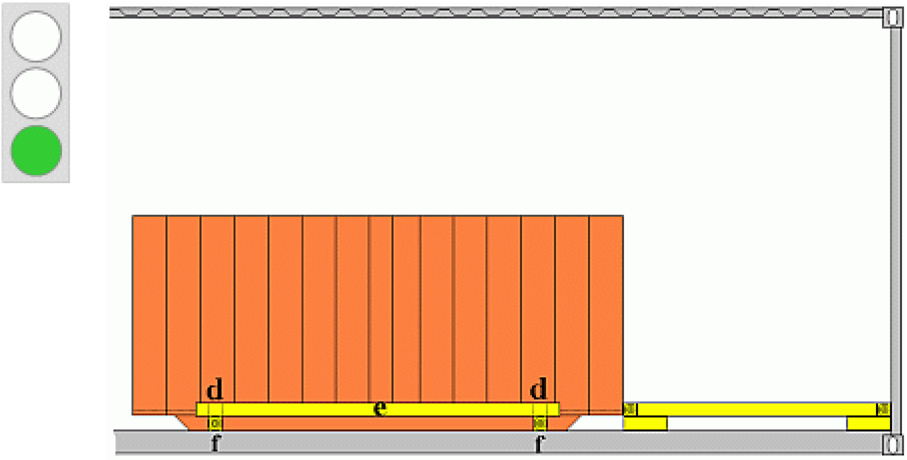
Once the case has been loaded, the space at the right of the container can then be braced:



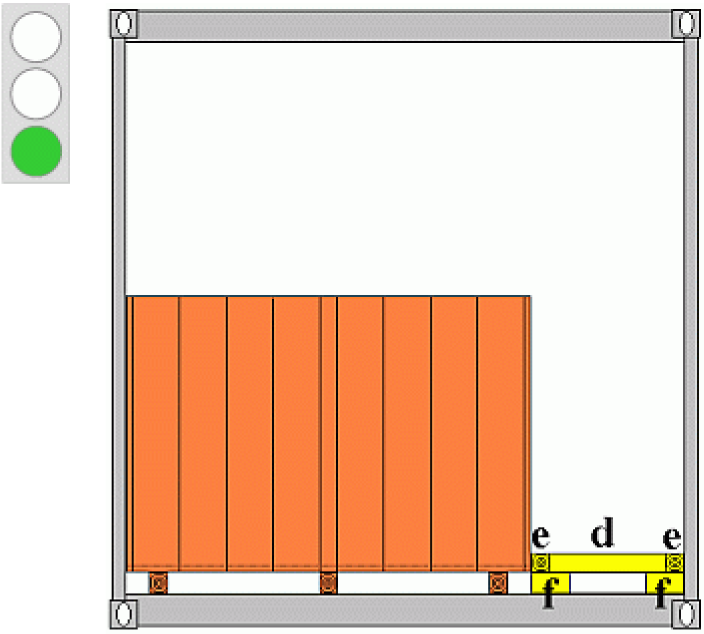
Bracing in the space at the right of the container - Plan view

The wooden bracing elements (d) and the wooden beams that are designed to distribute the load forces (e) are raised by beams placed below them to the extent that the frame is at the same level as the robust bottom of the case. The number of wooden elements used to form the bracing will depend on the weight of the case and can be calculated using a rule of thumb. For each square centimeter cross-section of a wooden element, a force of 30 daN can be absorbed.

The next two images illustrate more clearly how the frame is raised using wooden elements (f).



Bracing in the space at the right of the container - View from the right



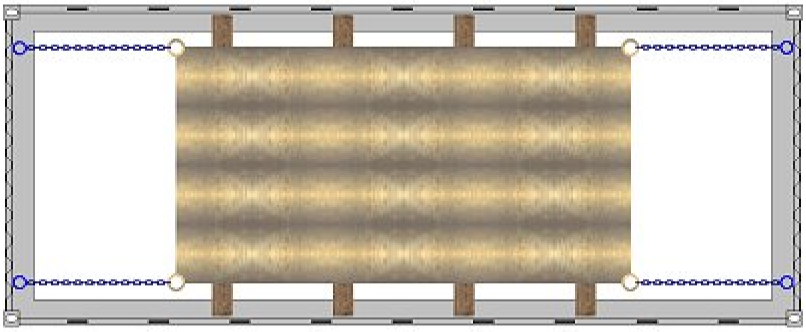
Bracing in the space at the right of the container - View from the door

If cases are at risk of tipping, they must also be braced close to the lid of the case. This is not necessary in this particular instance.

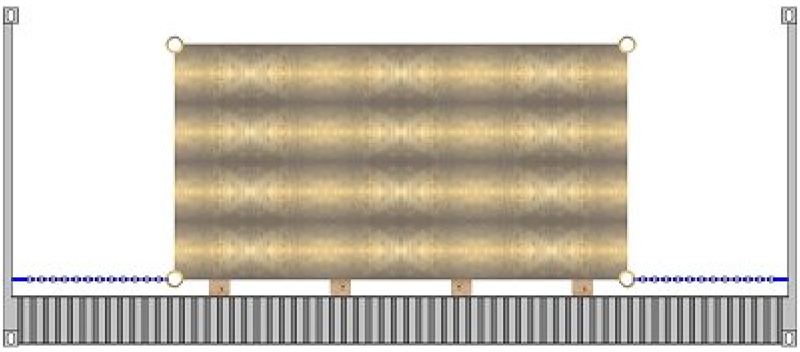
4.3.5 Achieving a tight fit by lashing

Lashing refers to the use of steel strapping, chains, steel wire, textile straps, ropes and other securing materials which are fixed, on the one hand, to the package and, on the other hand, to the CTU and then tensioned lightly. The important factors that determine the effectiveness of the lashings are the quality of the materials and the fixing points as well as the directions in which the lashings work. This means that lashing angles also play a critical role. Lashing a package is intended to prevent it from moving longitudinally or laterally and to stop it rising from the loading surface or tipping. A lashing is used to create a tight fit. The term direct lashing is also used.
The quantity and thickness of the required lashings will depend on the weight of the load that is to be secured, on the anticipated forces, on the maximum securing load of the lashings and the lashing angles. More information can be found in the relevant sections dealing with the materials and in the lashing examples.

Lashing has a less important role to play when securing packages in box containers. Since the lashing points in the container usually have a maximum securing load of 1,000 daN (corresponds to a mass of approximately 1 t), the use of lashing must be restricted to lighter packages. Another consideration is the fact that lashing points are often not accessible as a result of spatial restrictions and the space occupied by packages. When securing loads in open top containers a higher MSL can generally be assumed - often in the region of 2,000 daN (corresponds to a mass of approximately 2 t). Platform-style containers, on the other hand, offer good lashing facilities, which means that lashing is virtually indispensable on such cargo transport units.

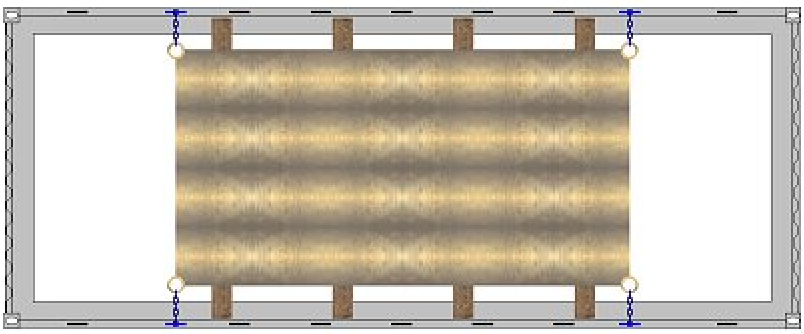


Horizontal lashings with longitudinal components - View from the top



Horizontal lashings with longitudinal components - View from the side

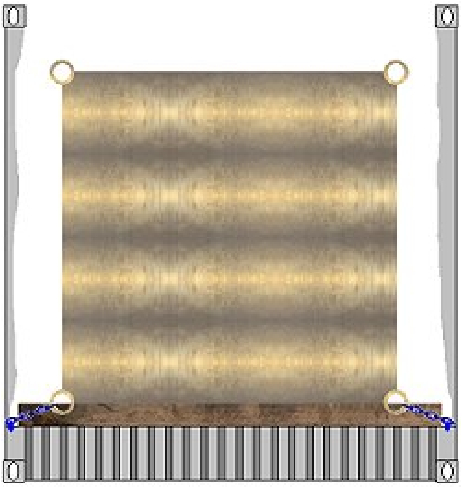
Horizontal lashings have no vertical component. Horizontal lashings attached longitudinally, as shown here, have no lateral components. The package is simply held in place longitudinally by this type of load securing.



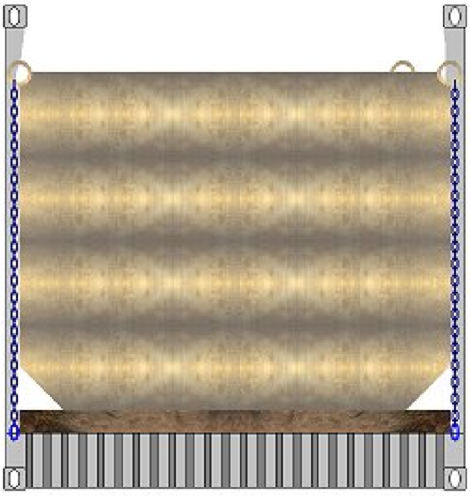
Horizontal lashings with horizontal components - View from the top

If the lashings are absolutely parallel to the horizontal transverse axis, they will have no longitudinal or vertical components. A package secured in this manner is thus exclusively secured in the transverse direction.

The lashing shown here, however, also has a slight vertical component as a result of the position of the lashing points.

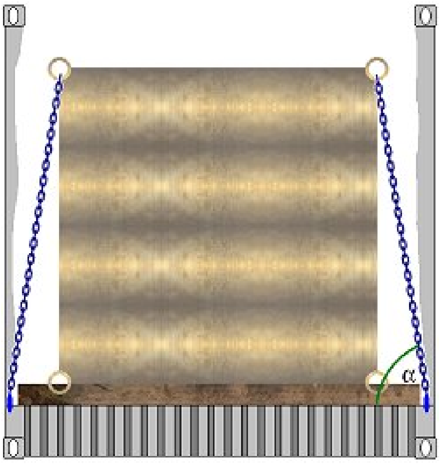


Horizontal lashing with transverse and vertical components - Lateral view



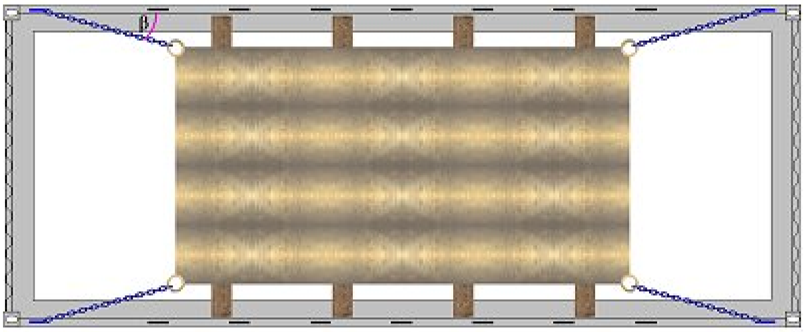
Vertical lashing without horizontal components - Lateral view

A purely vertical lashing has no horizontal component at all. These lashings are thus unable to exert either a longitudinal or a transverse securing effect. Longitudinal and transverse forces can cause the load to move. If this happens, the purely vertical lashings are displaced sideways and sometimes placed under considerable tension. The tension that is created as a result of the load moving exerts a force on the load pushing it down on the container floor. This increases the frictional forces on the floor. Frictional forces for each lashing are calculated using the product of the MSL and the friction coefficient.

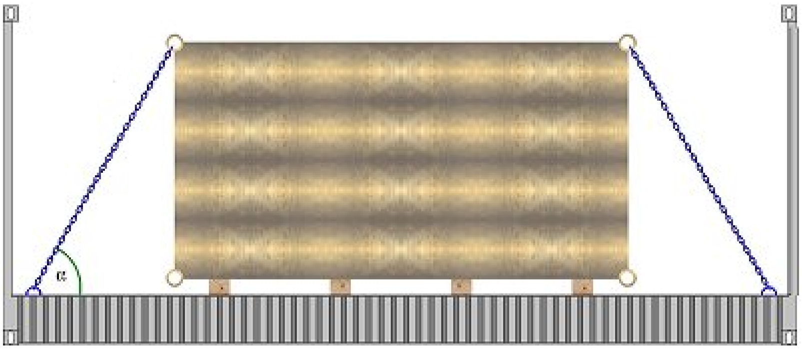


Vertical lashings with slight horizontal transverse components - Lateral view

The German VDI guidelines refer to lashings of this type as inclined lashings. Such lashings form a lashing angle with the horizontal plane, which is referred to as α.



Diagonal lashings with horizontal longitudinal and transverse components and vertical components - View from the top

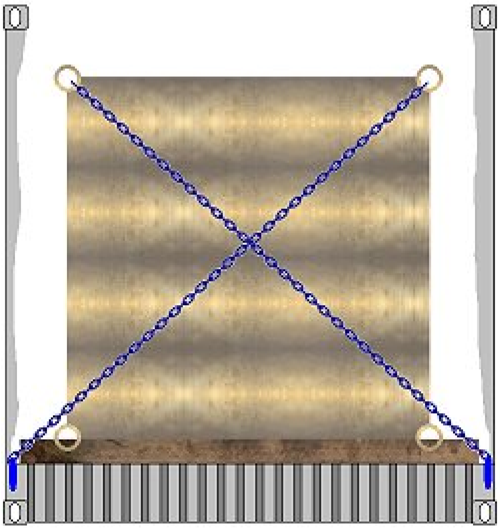


Diagonal lashings with horizontal longitudinal and transverse components and vertical components - View from the side

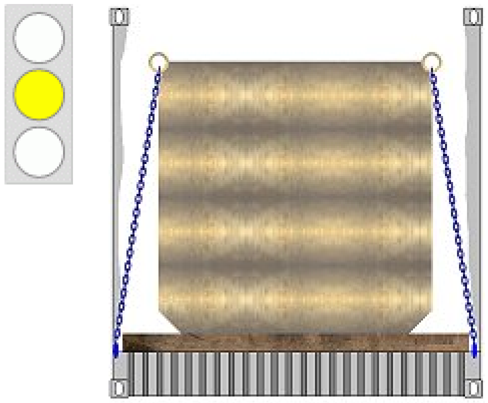
Diagonal lashings form a lashing angle α with the horizontal plane and a further lashing angle β with the horizontal longitudinal direction of the transport unit. According to the terms defined by the VDI, lashings of this type are referred to as diagonal lashings.

With the diagonal lashings shown here, the vertical components are the greatest. The horizontal longitudinal components are considerably smaller, and the horizontal transverse components even smaller still.

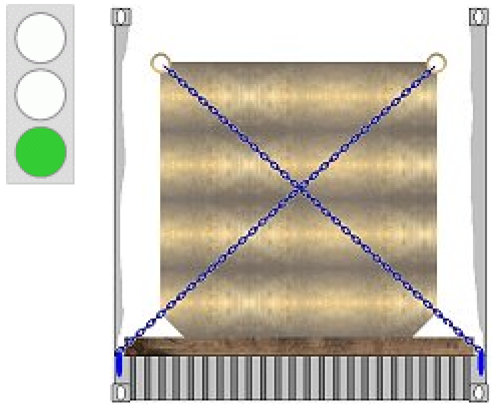
Cross lashings are simply a special form of diagonal lashing. These are advantageous if the lack of space requires greater horizontal components.



Cross lashings with horizontal and vertical components
- Lateral view

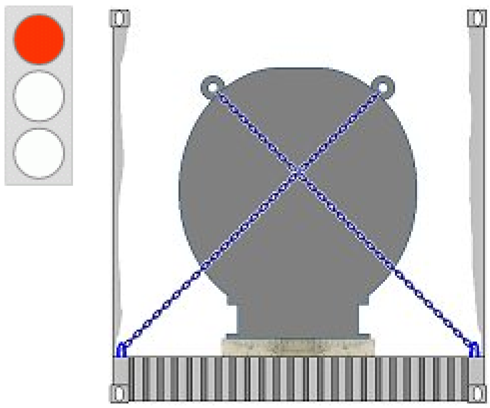


Diagonal lashings with small horizontal transverse components

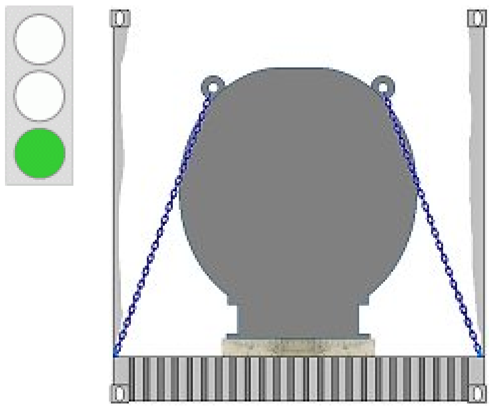


Cross lashings with better horizontal transverse components

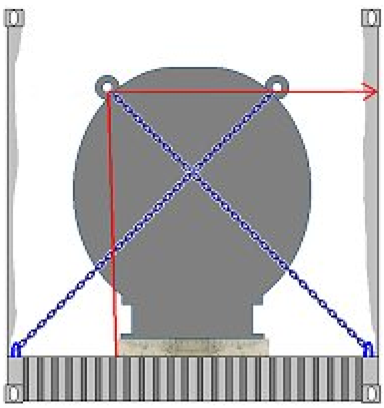
The package on the right is considerably better secured laterally than the one on the left. Under such conditions cross lashings are often suitable. But beware: This no longer applies if the package is to be secured against tipping.



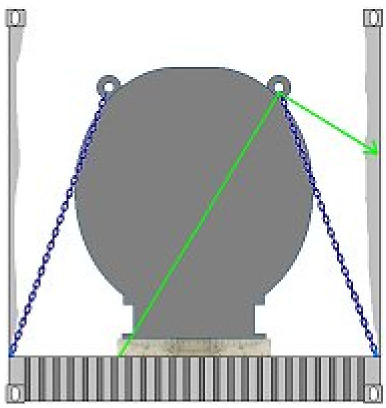
Ineffective components for securing against tipping



Effective components for securing against tipping



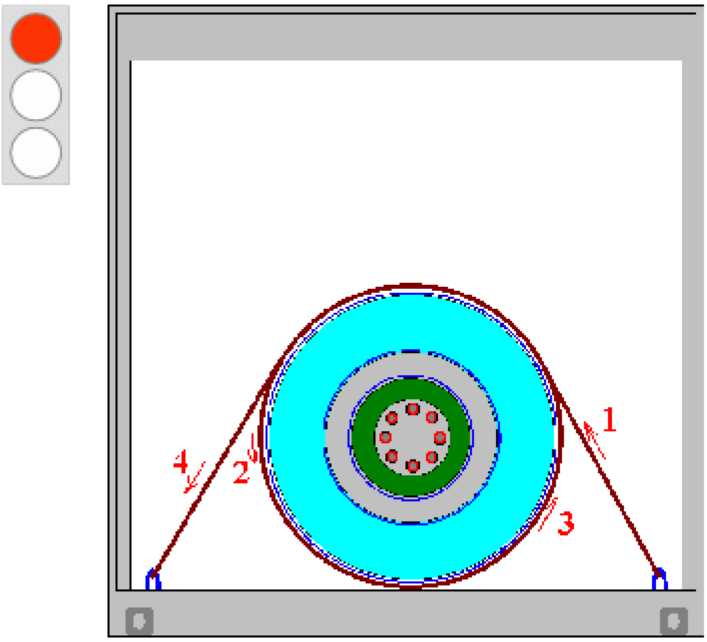
Optimum lashing angle to protect against tipping, but impossible to implement



The real lashing angle is close to the optimum to protect against tipping.

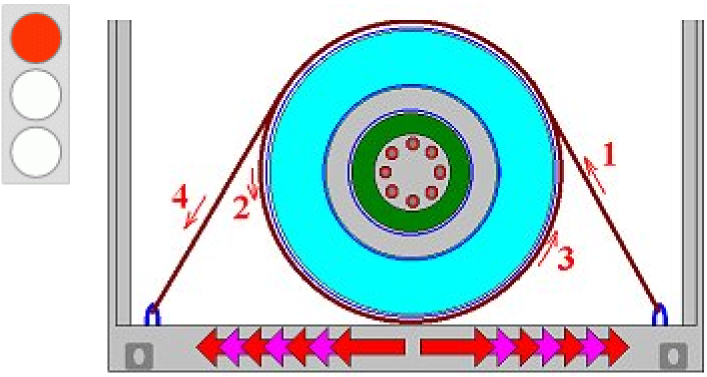
The optimum angle for securing against tipping is to imagine a line to the outside at right angles to the line connecting the lashing point and the tipping edge:.

A clear warning must be issued against the so-called round turn lashings where the lashing material is fixed at one side, wrapped around the object and then fixed at the other side:



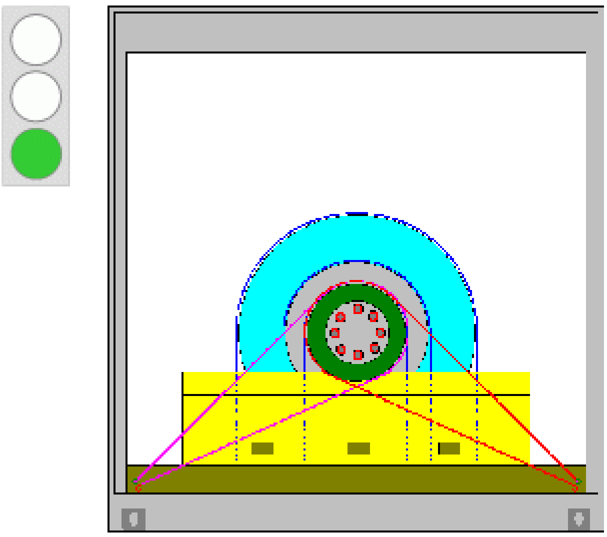
Round turn lashing

Round turn lashings allow the loads to move freely.

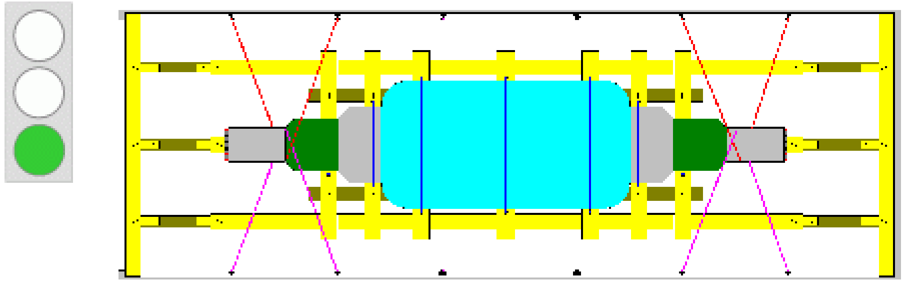


Round turn lashings are similar to the diabolo toy principle

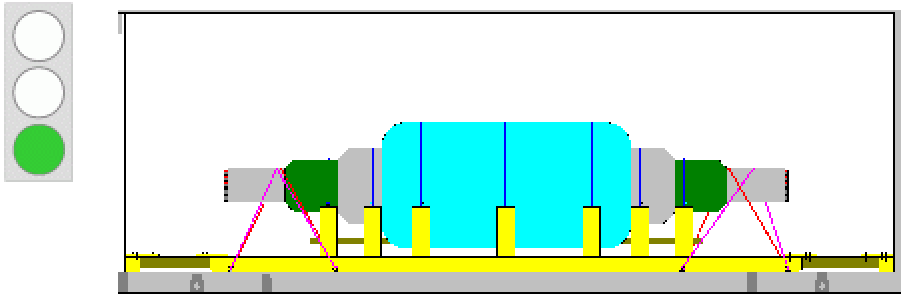
Loop lashings are unfortunately rarely used as a form of tight-fit securing although they are extremely effective. This method can be used very effectively with all long, cylindical loads.



Loop lashing used to secure a piece of machinery - Lateral view

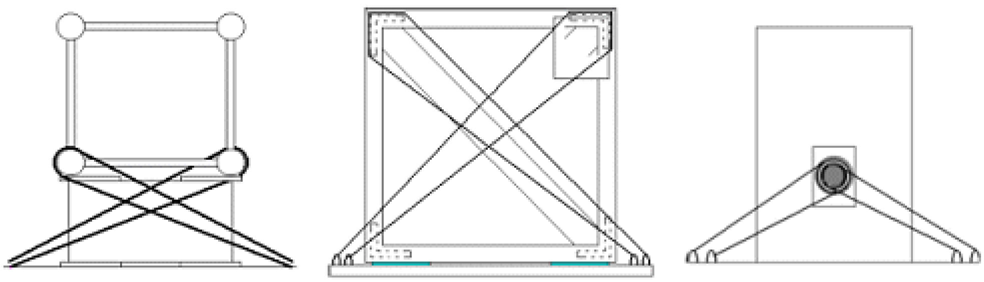


Loop lashing used to secure a piece of machinery - View from the top



Loop lashing used to secure a piece of machinery - Side view

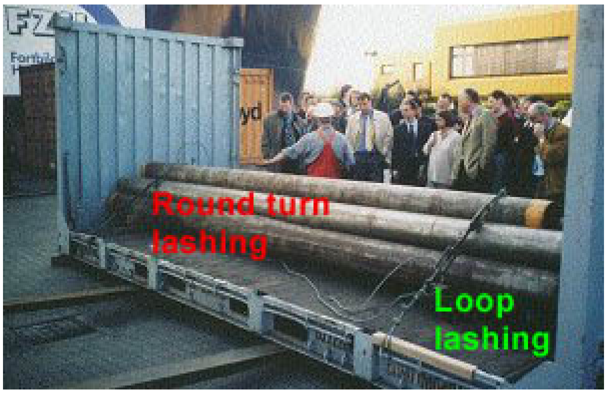
Loop lashings can be used anywhere where the lashing can be wrapped around a component of the load. To create a loop lashing, the lashing material is fixed to a lashing point on the means of transport, wrapped around the load and back to the side it started from and, if possible, secured to a second lashing point.



When using separate lashing points, the permitted lashing force of a single strand of the lashing can be increased by a factor of up to two at best. With a lashing point with a permitted load of 2,000 daN (approximately 2 t) and a permitted lashing force of a single strand of lashing material of 2,000 daN (approximately 2t) as well, this will result in a maximum of 4,000 daN (approximately 4 t) securing force. The opening angle between the ends of the lashing material leads to a certain reduction: With a maximum possible angle of 90° in the three diagrams this is 30%. The pretensioning force in the lashing will also reduce the securing force. However, depending on the circumstances, the frictional forces may be increased.

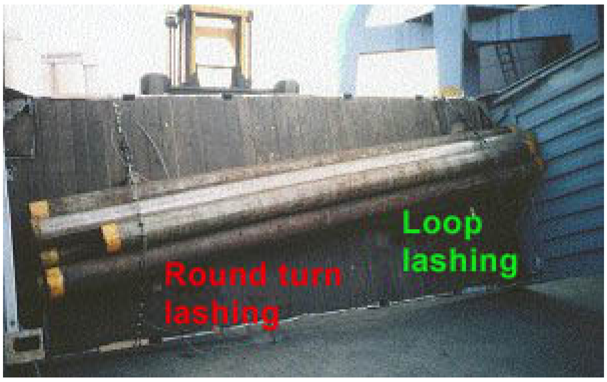
There are numerous possible variations on the loop lashing principle. A little imagination and experience will show that this principle can be used to solve a multitude of load securing problems.

The weaknesses of the round turn lashing and the strengths of the loop lashing have been investigated by the Fortbildungszentrum Hafen Hamburg (the training center at the port in Hamburg) in a very effective test. Part of this series of photos is shown here:



The lashings have been applied - The tipping process begins.

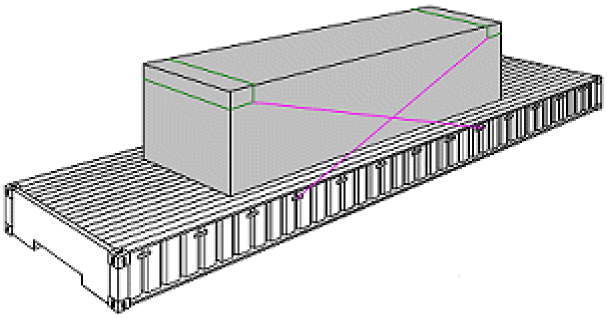
An angle less than 30° has been reached - part of the friction forces are still effective.



The round turn lashing fails, the loop lashing remains firm.

Impact: The round turn lashing fails even more, the loop lashing still remains firm!

If there are no securing points, lashings can be attached with "head loops".



Head loops with spring lashings in the form of a cross lashing

Note that the lashing shown in this sketch is not sufficient for carriage. It is only shown to illustrate the principle of head loops (green) and lashings attached to them (magenta). Securing using head loops will usually require two members of staff. This method is much too time-intensive to implement alone. The term spring lashing is used to described lashings that run from the outside to the inside, regardless of whether they cross. Head loops can take a number of different forms. This Container Handbook and the GDV Cargo Securing Manual contain a number of samples in the various examples.

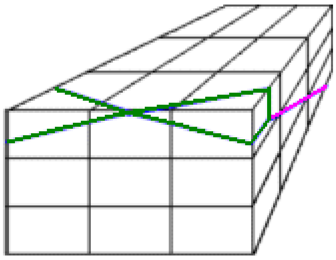
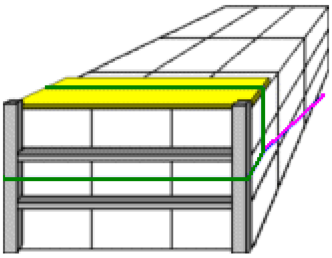


Figure of eight head loop

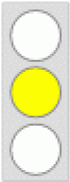


Head loop with padding

If layered goods run the risk of the head loop cutting in between the individual packages, then a figure of eight head loop can be used to achieve the same result. The use of the head loop as shown above, requires the packages to be stable enough to take the full MSL of the lashing. If this is not the case, boards, lattices, walking boards, square lumber dunnage and other similar aids can be used to cushion them in order to meet the prerequisites for the head loops. This is usually needed when securing bundles, IBCs, units, bagged cargo pallets, or other similar packages.

The majority of securing errors are made when making and securing the lashings. This picture shows the use of a hook which has already been bent open, and which has also been inserted in the wrong direction. The chain tensioner shown has not been used correctly. It must be tightened down by at least 45° and must not protrude at right angles as shown here, otherwise there is a danger that the link of the chain could escape from the lug of the tensioner. The lashing angles are not suitable. High vertical components have been achieved, but the longitudinal and transverse components are too low.

Faulty fixing and errors

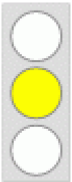


Tight-fit securing of rolls of paper using a WisaFix lashing cover

This example shows the use of a load securing tarpaulin with textile straps that have been secured to the ends of the roll trailer, thus ensuring a tight-fit. This type of securing is only suitable for ocean-going transport if the roll trailers are stowed in a "tight-fit" constellation next to each other and either along the length of the ship or athwartships. Since the load has simply been strapped down at the sides of the roll trailer, the securing is sufficient for terminal transport, but not for ocean-going transport.

4.3.6 Friction securing

Friction securing or friction loop securing means that the frictional forces between the packages and the intermediate layers or underlying surface are greater than the forces caused by transportation and which are working on the load. Only if this requirement is fulfilled when the load is packed and can be maintained during the entire transportation process, can the load be considered "secure". A simple example taken from everyday life is the passenger traveling on a bus who places their foot on top of their briefcase in order to prevent it sliding away from them in a corner or during acceleration and deceleration.

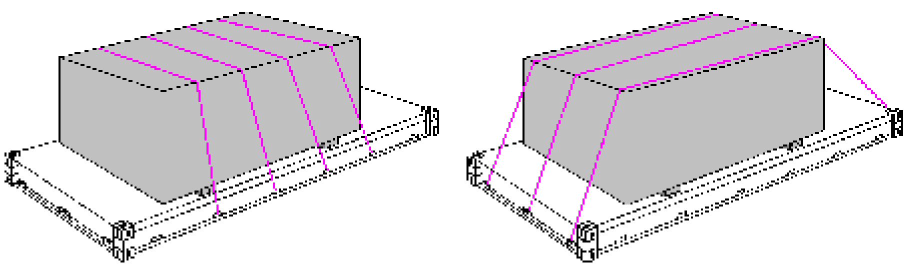


Friction loop made of steel strapping

The best-known and most frequently used form of friction securing is the round turn or friction loop. The VDI guidelines and other road traffic publications refer to this method as tying down, and to the lashing as a tie-down. The rail transport industry uses the term tie-down.

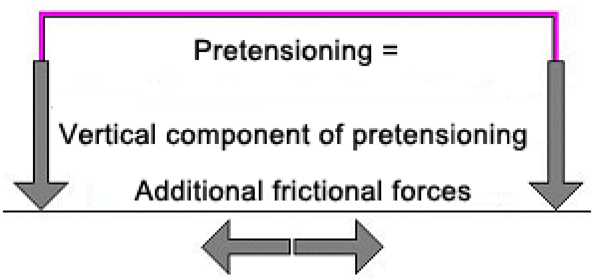
Whatever term is used, the guidelines are referring to the same method: With the aid of tensioning elements, a certain degree of pretensioning is introduced into the lashings which effectively puts additional artificial weighting on the secured package. This causes additional frictional forces on the bottom of the package. In conjunction with the "normal" frictional forces this will give the overall securing force of a given lashing. The effectiveness of this method of securing increases with the friction and the effective pretensioning.

If tie-down lashings can be referred to as "advantageous" at all, this is as a result of fact that the frictional forces act in all directions. Thus, it is not significant from which side of the object the tie-downs are applied.



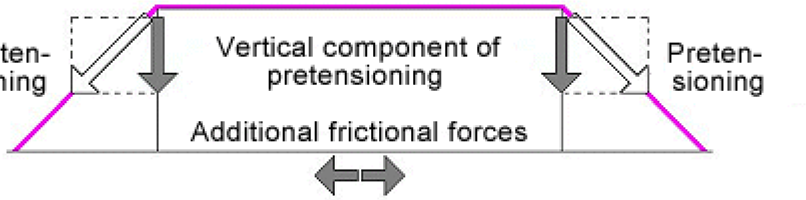
Frictional forces act in all directions.

The general securing principle is that the vertical components of the pretensioning force introduced to the lashing aid increase the downward pressure between the load and the surface it is resting on, thus generating additional frictional forces.



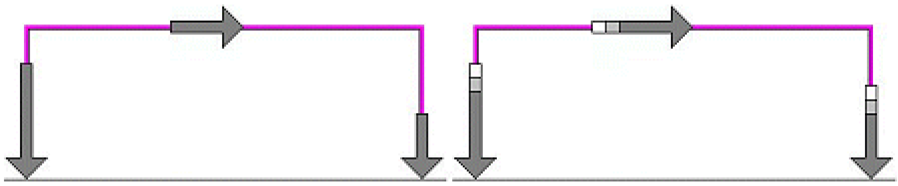
How tie-downs work

The smaller the vertical components and the frictional values, the lower the securing forces that can be achieved:



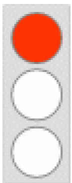
The relationship between pretensioning and the vertical component for lashing angles

Where tensioning aids are applied to just one side of an object, the pretensioning force decreases towards the opposite side. The rougher the contact surfaces over which the material passes, the lower the pretensioning force on the opposite side. The use of smooth edge protectors helps to ensure that as much of the pretensioning force created on the one side is distributed to the other as possible. Jolting may cause the pretensioning force on the tensioned side to decrease and to increase on the side that is not tensioned.



Migration of pretensioning force during transport

If it is not possible to use smooth edge protector corners with tensioners used on one side only, it is sensible to tension the lashings on alternate sides.



Incorrect installation of fixed lashing tensioners and steel strapping

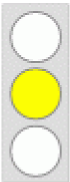
The lashing capstans would have been more useful if three of them had been installed on each side of the flatrack. Here, it is not ideal that all the steel straps are tensioned on the same side.

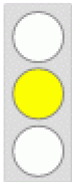
What is important is that the pretensioning force always remains constant. Thus, it is only sensible to use tie-downs with elastic materials. Wire rope, chains and even steel straps are unsuitable for use as tie-downs unless they can be rendered elastic by the use of special padding materials.




The securing forces only exist if the pretensioning force can be maintained.

This wooden case clearly shows that the steel strapping has left an impression in the wood of the case. Just a few more jolts and the pretensioning force will be reduced to nothing. The use of a piece of tire rubber, as shown in the picture on the right, can effectively help maintain the pretensioning force by making use of the elasticity of the rubber.






Steel wire and tire rubber **Decrease in the pretensioning force**

When transporting materials that give way easily, a padding with a high degree of recovery, like tire rubber, is not going to be very effective. As the picture shows, the loss of pretensioning force is dramatic. Here, a new 16 mm steel wire rope lost tension, dropping from approximately 2,700 daN to approximately 2,100 daN during a 20 minute coffee break. Unfortunately steel wire ropes tend to lose tension. In this example, however, the use of tire rubber is an ideal method of reducing damage to the tarpaulins and to the load.

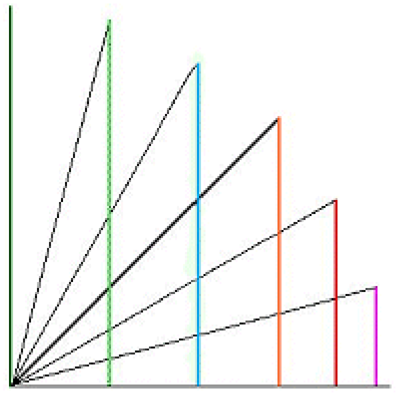
The magnitude of the pretensioning forces that can be introduced into the lashing material is dependent on the tensioning forces used, the leverage on the tensioning element and the elasticity of the lashing material. Experience shows that the following lashing materials are able to attain the following pre-tensioning forces in the lashing material when tensioned with normal physical effort:

- Normal ratchet tensioners approximately 300 daN per side
- Tensioner for single-use webbing approximately 500 daN
- Long-lever ratchet tensioners approximately 500 - 750 daN per side
- Commonly available spindle tensioners and capstans 500 - 1,000 daN
- Manual steel strap tensioners 1,000- 1,500 daN
- Lashing turnbuckles approximately 3,000 daN

These values are not definitive; they are based on practical experience gained in a sea port. Practitioners should calculate the appropriate values for their field depending on the materials used. The use of special tensioning aids may make it possible to apply greater pretensioning force. The use of pretension indicators is recommended. These allow both accurate measurement of the pretensioning force during lashing, as well as allowing the residual pretensioning force to be checked during transportation. However, it must be said that this is of little use if the containers cannot be checked during the transportation process.

For reasons that will not be explained here, the pretensioning force is only permitted to be, at the most, half of the MSL or the permitted lashing force of a single lashing.

The vertical component of the pretensioning forces decreases as the lashing angle of the tie-down decreases. From a mathematical point of view, the rate of decrease is by the sine of the lashing angle. The following values can be used as guidelines:

Lashing angle	**Magnitude of the vertical component**			**Graphical representation**
90°	**1.00**	**or**	**100 %**	
75°	**0.97**	**or**	**97 %**	
60°	**0.87**	**or**	**87 %**	
45°	**0.71**	**or**	**71 %**	
30°	**0.50**	**or**	**50%**	
15°	**0.26**	**or**	**26%**	
0°	**0.00**	**or**	**0%**	

Influence of the lashing angle on the vertical component

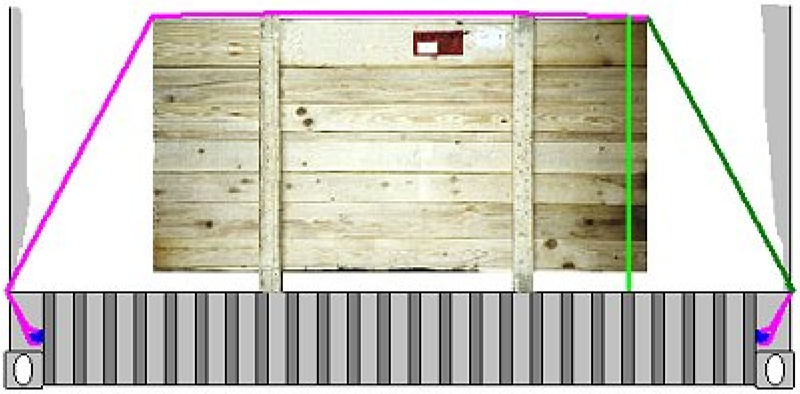
The table below shows examples of the magnitude of the overall securing forces of tie-downs with a total pretensioning force of 600 daN when used with various lashing angles and coefficients of friction.

Total pretensioning force in daN	**Lashing angle**	**Vertical component**	**Friction**						
			0.10	0.20	0.25	0.30	0.40	0.50	0.60
600	15°	0.26	16	31	39	47	62	78	94
	30°	0.50	30	60	75	90	120	150	180
	45°	0.71	43	85	107	128	170	213	256
	60°	0.87	52	104	131	157	209	261	313
	90°	1.00	60	120	150	180	240	300	360

Securing forces depending on pretensioning force, lashing angle and friction

The table shows that with a total pretensioning force of 600 daN, a lashing angle of 90° and a coefficient of friction of 30% it is possible to achieve a securing force of 180 daN per tie-down. Thus, in order to secure a load with a mass of 9 t, 50 (fifty !) tie-downs will be required. This shows that tie-downs have only limited use as securing aids. In addition to this, tie-downs require an equal distribution of the pretensioning force on both sides. This can be achieved by using tensioning elements in pairs, centrally or alternately.

The effective securing forces can be very accurately calculated on site with very little effort and some basic mathematics, as long as the pretensioning and frictional forces are known or can be estimated with some accuracy.



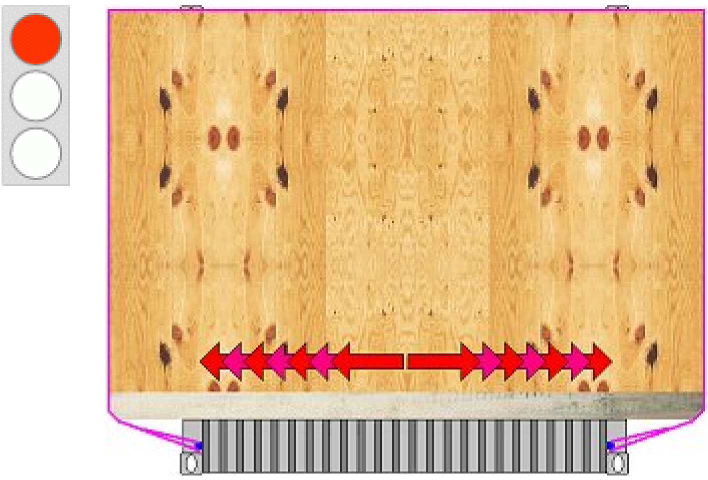
Determining the vertical component of the pretensioning force of a lashing

The effective length of the lashing aid in the example is measured at 1.00 m (dark-green line). The vertical component of the lashing in the example is 0.80 m (light-green line). The vertical component of the pretensioning force is thus 80% or 0.8 (always divide the smaller value by the larger value). Multiplying the value with the pretensioning force of the lashing aid and the coefficient of friction between the package and the surface will give the securing force. With a pretensioning force of 500 daN and coefficient of friction of $\mu = 0.3$, the lashing applies a securing force of 0.8 x 500 daN x 0.3 = 120 daN.

Using conventional materials it would be possible to use tensioners on both sides - but this is not practical. The central use of tensioning aids in container loads is a potential source of accidents since staff need to climb on top of the load. Prefabricated load securing materials usually only have tensioning elements that are not located in the middle and would thus require additional outlay in terms of material and work. Thus, it is recommended that tie-downs should be secured on alternate sides if they are used at all. Shifting of the load is more likely to occur if the tension is not distributed equally. Tie-down lashings can only be used in box containers under certain circumstances. They are easy to use with all forms of platform container, but are not to be recommended.

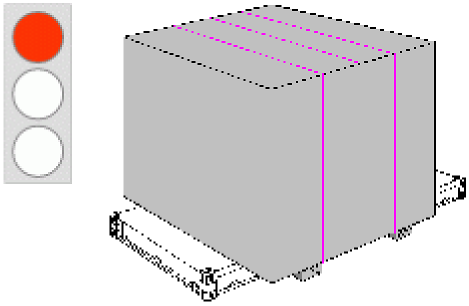
As has already been mentioned, in order to ensure adequate securing of the load, it is necessary to maintain the pretensioning during the entire transportation process. Even the slightest of gaps in the load, the settling of the load, yielding or compression of the load, or the cutting of lashing aids into the load as a result of a lack of edge protectors can all reduce the pretensioning force to zero.

Loads which have an overhang are unsuitable for tie-down lashings for another reason:

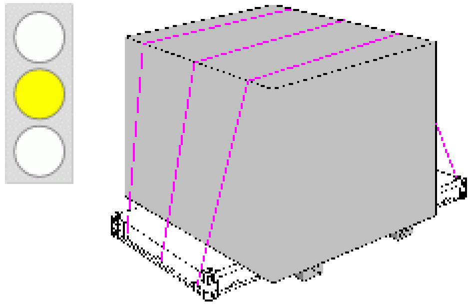


Potential movement of the load caused by too little securing force applied to a wide load

As a result of the unsuitable lashing angle in the lower area, it will be practically impossible to attain sufficient pretensioning force regardless of the type of lashing material used. Thus, the risk is particularly high that the package will shift during transport.



Poor



Not good, but better

To summarize, friction loops or tie-downs can only really be used as an effective form of securing if there are no gaps in the stow, or if any gaps are filled. With small gaps, the use of wedges or tapered blocks is recommended. Larger gaps in the load should be braced using wood or another equally strong material. It must also be possible to create sufficiently high pressure. If this is not possible, loads should be secured using other methods. Lashing materials without sufficient elasticity are not suitable for use as tie-downs. Those with a suitable degree of elasticity, for example lashing straps, will gradually lose their pretensioning force during use. This process will be accelerated if the load is exposed to vibrations.

Tie-downs must thus be checked and, if necessary, tightened at regular intervals. Since this is not possible when a load is stowed in a container, tie-downs are not suitable for securing loads inside containers. Again: If another method of load securing can be used, tie-downs should be avoided!

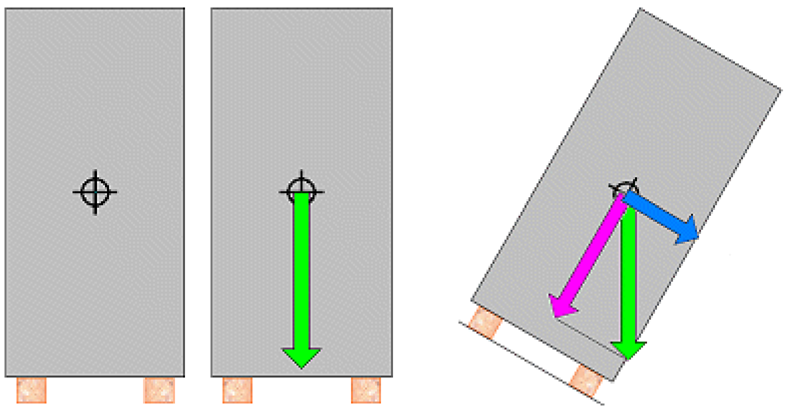
One thing tie-downs always do is to create a direct lashing acting against vertical movement.

Friction securing can also be achieved using wedges. Another variation is to to put pressure on the load forcing it down. In the event of an absence of available/accessible lashing points, this method of securing may be used in box containers. The prerequisite is the accessibility of components of the means of transport that are able to withstand this load.

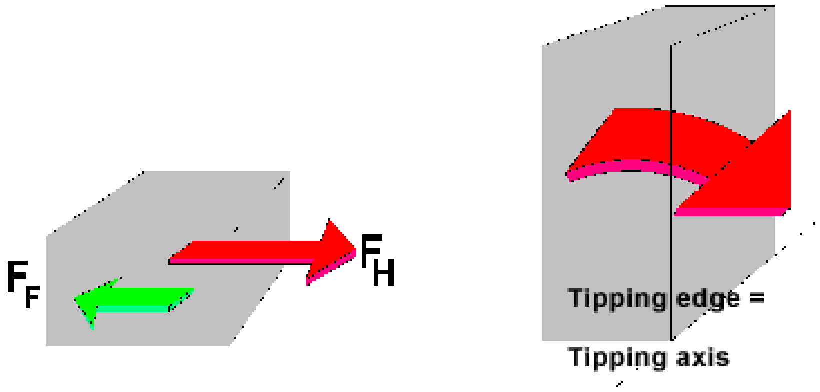
Principle of downward pressure - Example

Depending on the magnitude of the securing forces to be created, the sensitivity of the packages and the resilience of the components of the means of transport, squared lumber, planking and boards can be used. Caution: At very sharp angles, driving the diagonal stays in laterally can create extreme vertical forces.

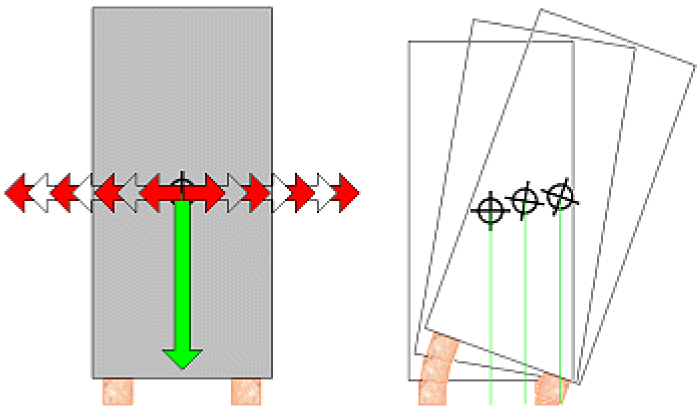
4.3.7 Securing against tipping and other hazards



The stability of packages will depend on the position of the center of gravity and the load bearing area. Gravitational forces act on the center of gravity. These act vertically and downwards. On a steep incline, the gravitational force is divided into two components: one acting vertically to the plane and one in the direction of the slope, the shear force. Each of these forces acts on the center of gravity.

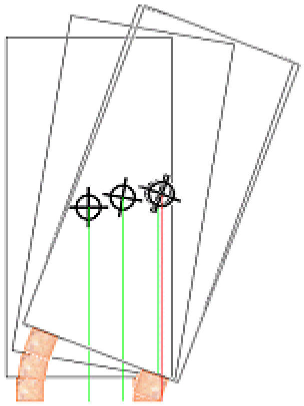


Inertia forces arising as a result of a change in speed or direction within a given time period will also act on the center of gravity. They may cause packages to slide or topple.

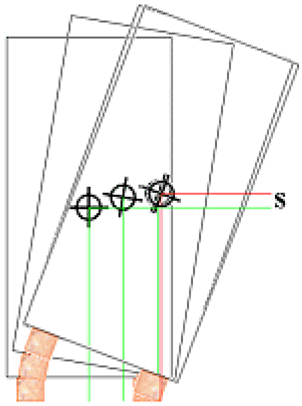


Horizontal forces and gravitation **Tipping goods**

When an object tips, the center of gravity is raised. If the center of gravity remains within the tilting edges, the package will return to its normal position, as soon as external forces cease to act on it.

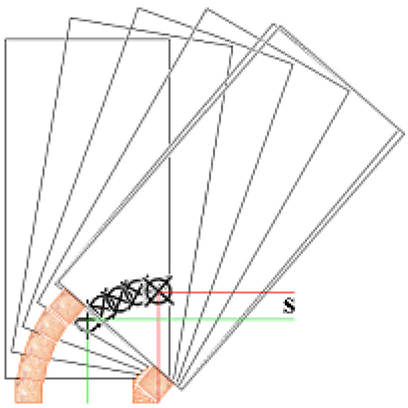


Unstable position

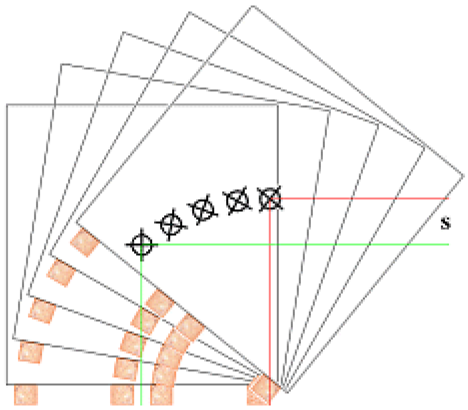


Lever arm of the stability moment

If the center of gravity of an object is located directly over the tilting edge, the package is unstable. The degree to which the center of gravity must be raised before it reaches that position is a measure of the stability of the object. The product of the weight of the object and this distance gives the stability moment.

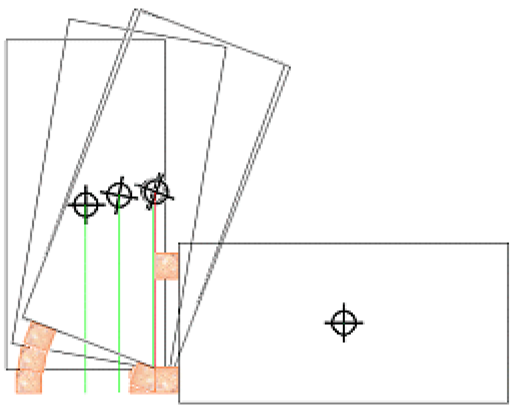


Large stability moment



Larger stability moment

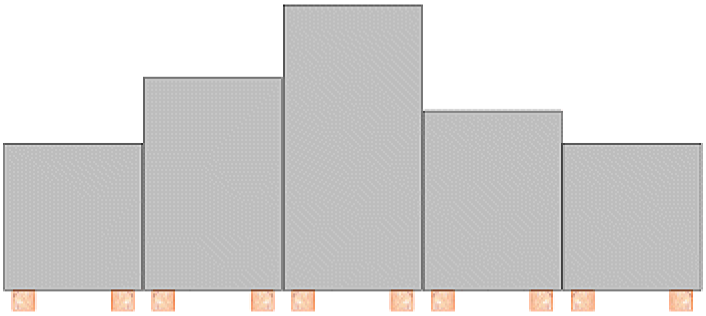
The lower the center of gravity, or the greater the lower surface area of the package, the greater the stability moment.



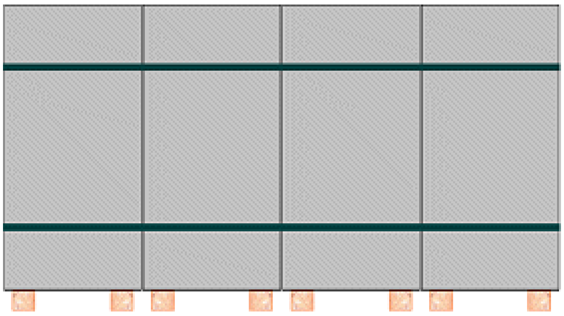
Toppling

If the center of gravity moves beyond the tilting edge then the package will topple.

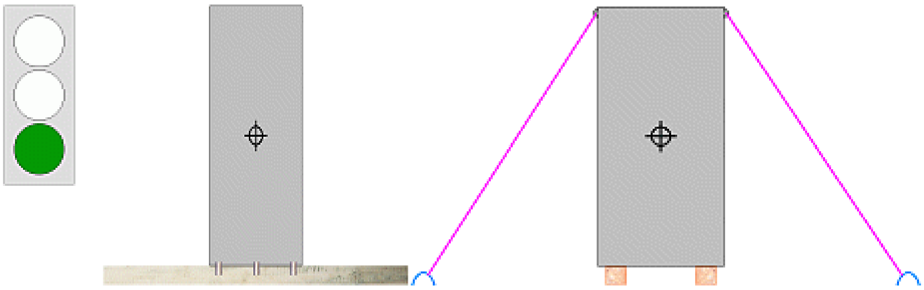
A number of different methods can be used to prevent tipping.



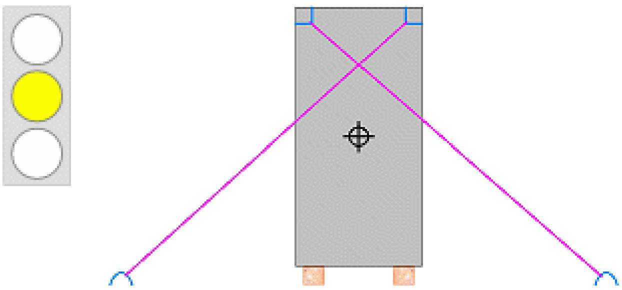
Combining a number of units that are liable to tip to form a single block



Bundling

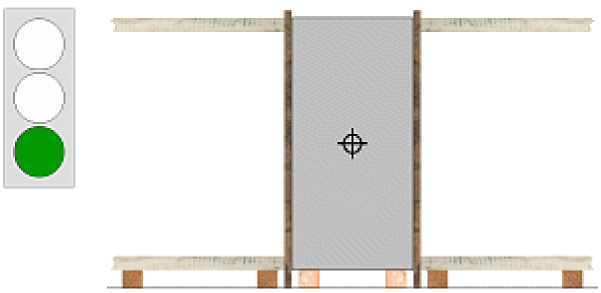


Increasing the lower surface area by using blocks or lashings

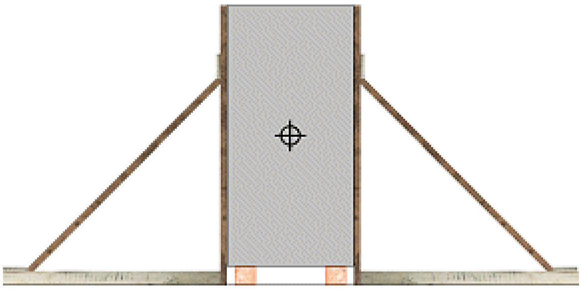


Lashing with head loops in the absence of lashing points

Caution: When using this method, the opposing forces created are not as high as those sketched previously.



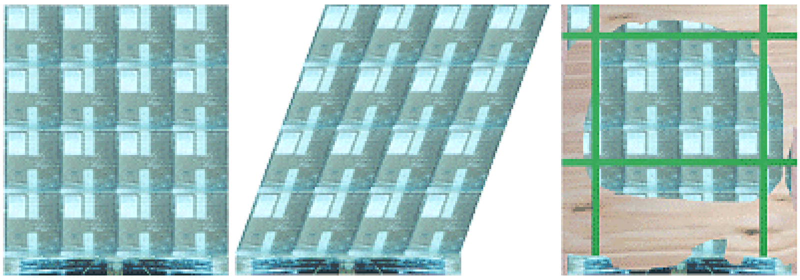
Using bracing elements to prevent tipping



Using diagonal stays to prevent tipping

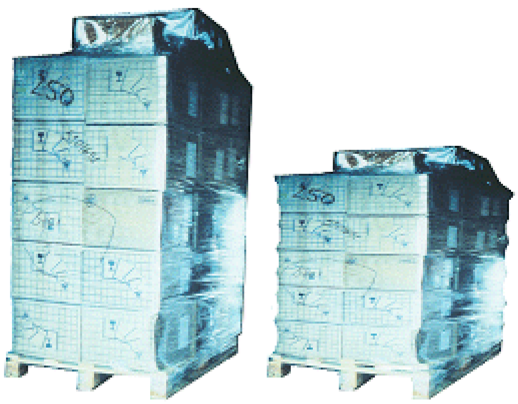
Caution! This method is recommended in a number of publications, including the CTU guidelines. Be warned. Our tests have shown that the uprights can be levered out of position. The steeper the angle, the greater the risk.

The packing and formation of load units is responsible for protecting against shifting or racking:



Shifting or racking

Improvements must be made if packages or unit loads are clearly too weak. This may be done using walking boards, wooden lattices etc. and additional strapping.

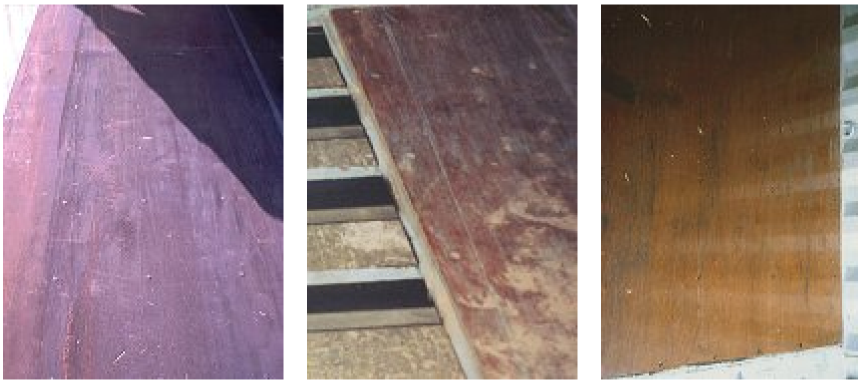


Before - After **A collapsed unit load**

The collapse of an entire unit load as a result of packaging that is not strong enough and/or excessive stack loads can be avoided by selecting out or rejecting packaging that is not strong enough, by improving the packaging, employing sufficient interlayer dunnage and by building "dummy decks".

4.3.8 Securing by nailing

A popular method of securing loads is to use wooden constructions that are fixed by nailing. Squared lumber and wooden wedges are generally used, but also planks and battens. These solid wooden constructions can only really be effective if the nails used are strong and long, and can penetrate deep into the wood and into a surface which will take nails.



Container floors

Container floors generally have a thickness of just 25 - 30 mm. Also, the majority of floor types will be damaged by the use of nails. Thus, these methods cannot really be recommended for securing in containers. They could be used on softwood planking, as is sometimes used on platform containers, but are not suitable as the only form of securing for heavy goods. Another variation is to create an additional, strong, specially-designed base made of planks or squared lumber beams and driving nails into this.

Wooden beam 5 cm x 12 cm

If the method is not used for light packages that are at risk of tipping, as it usually is, then it must be ensured that only top-quality wood is used, with a thickness of at least 50 mm. Top-quality in this case means, healthy, free from cracks and dry. Shear strength and extraction resistance are influenced by the diameter of the nails, the penetration through the wood, the penetration into the underlying surface, the angle at which the nail is driven in, and the properties of the nail surface. Nails with grooves or with coatings will have higher resistance than ordinary wire nails.

Experience suggests that a nail, 5 mm thick, that is driven in vertically and which penetrates through 50 mm of the grain side of a piece of wood, and is driven in to a depth of 40 mm can be expected to offer 400 daN of resistance. Our own testing suggests that this value can be halved for wet wood. If the nail is driven in along the grain the values can also be halved. The resistance values are also influenced by the pattern of nails in the wood and the distance between the nails.

Securing using wooden beams

Nail strip for a nail gun

Nails should always be driven in vertically or at a slight angle to the direction of loading. They should not be too close to the edge of the piece of wood, and should not run in a line along the grain. Nails can be driven in efficiently using a compressed air nail gun. Magazines of nails, either rolled or in strips provide a source of nails that can be used with very little physical effort.

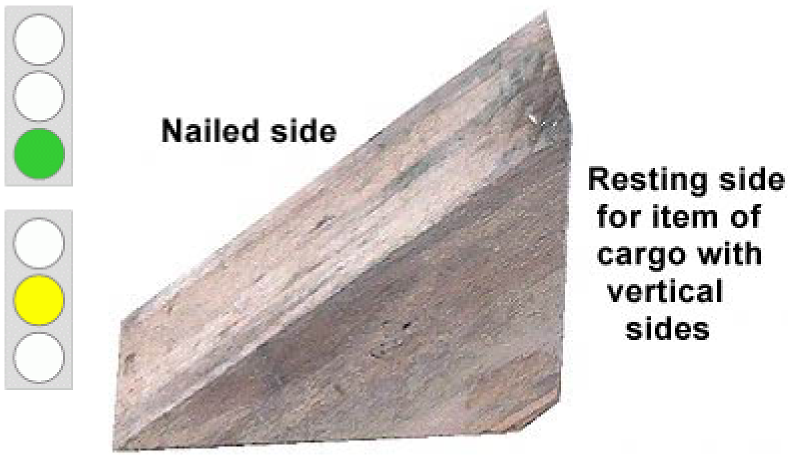
When using wedges to secure loads, badly cut wedges are often selected. Basically, wedges should be cut and positioned in such a way that the long side of the wood, i.e. the grain side, is the side that is nailed, and not into the grain.

Correctly cut wedge for securing cylindrical objects

Wedges of this type are also called chocks, roll or pipe wedges. The critical factor is that the grain side of the wood is available to take the nails.

When used as a wedge for loads with vertical surfaces: Wrong

This is the same wedge, but now it is placed differently. If a packer were to use this to secure a case, they would need to drive a nail into the grain. The wedge would split either during nailing or on one of the first jolts during transportation. Tests have shown that when wedges are used incorrectly barely half of the resistance values are achieved than would be achieved if used correctly.



(Almost) correctly cut wedge for goods with vertical surfaces

A wedge of this nature can be referred to as a crate wedge. Here, it is obvious what is meant. The nail can be driven into the grain side - and rightly so. However the slope of the flank is too steep.

Correctly cut crate wedge

Here the slope of the flank is much better suited to the requirements of a crate wedge.

When used as a wedge for cylindrical objects: Wrong

If the crate wedge was to be turned the other way, it would make an incorrect pipe wedge.

Sawing patterns for pipe wedges

There is no waste material when cutting pipe wedges. Any flank angle is possible. The right angles are always at the outside edge of the piece of wood.

Sawing patterns for crate wedges

When cutting crate wedges, make one cut at the required flank angle and then continue at right angles. Any flank angle is possible. The steeper the starting angle, the slimmer the wedge. The right angles are always on the inside of the piece of wood.

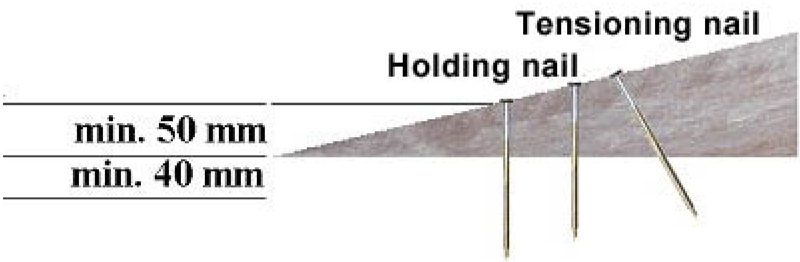
If the packers are using wedges for both cylindrical and right-angled loads, a plentiful supply of both types should be made available.

Pallet with pipe wedges **Pallet with crate wedges**

As a general rule, however, very little attention is paid to the instructions described here:

Incorrectly cut crate wedges, or pipe wedges used as crate wedges

It can be seen clearly that the wedges have already started to split. The function and effectiveness of the nails are to be doubted. They appear to be located too high up to fulfill the following requirements: For each wedge, at least three nails are necessary, one tension nail and two to hold the wedge in place.



Minimum conditions for nailing wedges and boards

The tension nails have the task of pulling the boards and wedges close to the load in order to eliminate any damaging gaps.

Nails in boards (left: holding nails, right: tension nails)

With boards, the nails can also be driven in against the direction of loading.

Wedge-shaped board cut to fit

This type of securing with wood is not usually capable of achieving the result expected of it.

Securing that has no effect

This form of board is not able to counteract the nail being lifted out of the floor.

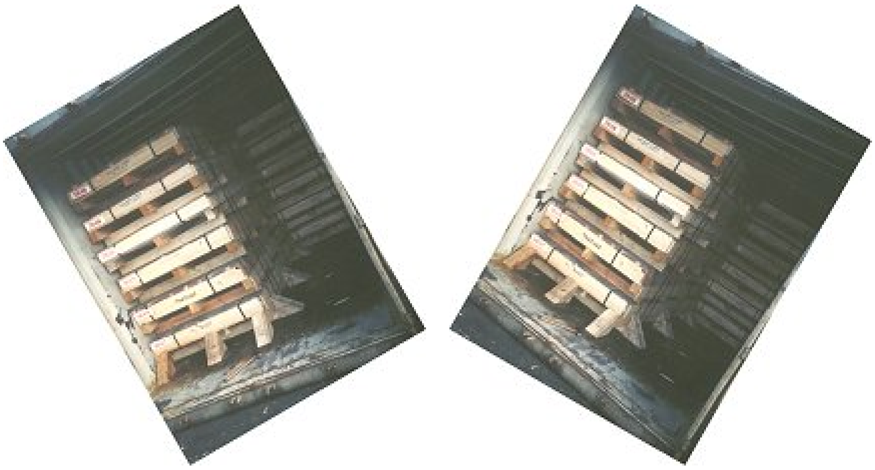
Wrong type of wedge, in the wrong place

This wedge has been cut incorrectly. It has thus already split as a result of a hammer blow or a jolt during transportation. The effective height is too small, the nails can easily be levered out.

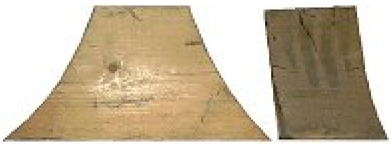
Incorrectly cut wedges

Incorrectly cut wedges

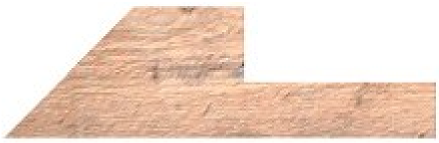
Correctly cut wedges - but insufficient securing



Simulation of a 30° roll angle of a vessel



Radial wedges



**Tank wedge with
a nose for the nail**

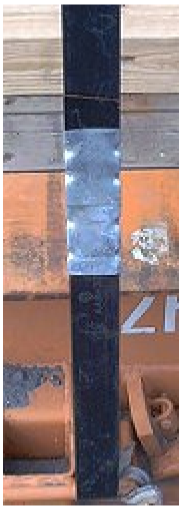
Specially designed wedges of a variety of shapes can be used to secure special types of load. The securing effect is achieved by the shape of the wedge itself. The nails serve purely to hold the wedge in place.

4.4 Load securing equipment

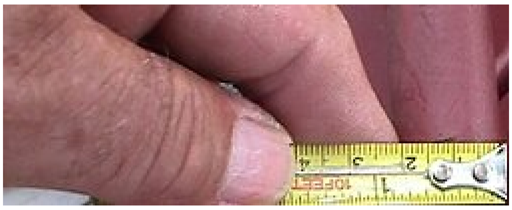
This section of the Container Handbook deals with how to determine the maximum securing load of materials used for load securing using simple rules of thumb and explains some basic principles for practical work.

Steel wire rope

Lashing point



Steel strap



Inspecting and measuring lashing equipment

Note: Sections in italics have been reproduced from seminar material by kind courtesy of Captain Hermann Kaps, professor at the University of Applied Sciences in Bremen.

Fundamental terms

kilonewton (kN) is a unit of force useful for describing for instance the breaking strength or breaking load of load securing material. It has replaced the previously common metric ton which is the unit reserved for describing mass according to the SI standard. The conversion is easily learned: 1 kN ≡ 0.1 t or 100 kg.

Anyone who was used to calculating mass in kilograms can use the unit decanewton (daN) as a unit of force.

The following English terms are in common use in maritime transport across the world.

Securing element *is an individual item of equipment on board ship which is used for load securing, e.g. a shackle, a deck ring, a turnbuckle, chain or wire rope.*

Securing device *is a suitable combination of elements which together form a means of load securing, e.g. lashing or bracing.*

Securing Arrangement *is a reasonable arrangement of load securing means with the aim of securing a cargo item or a cargo block.*

Breaking Load (BL) *is the nominal breaking load, generally specified by the manufacturer. However, it can also be estimated using rules of thumb.*

Maximum Securing Load (MSL) *in kN, is the greatest permissible force which can be applied to a load securing element or device.*

Calculation Strength (CS) *in kN, is an arithmetic force determined by reducing the MSL by the formula: CS = MSL / 1.5. CS values are only used to assess the efficiency of securing arrangements as per Annex 13 of the CSS code.*

The relation between Breaking Load and Maximum Securing Load is shown in Annex 13 by the following table:

Material	MSL
Shackles, rings, deck eyes, turnbuckles of mild steel	50% of breaking strength
Fiber ropes	33% of breaking strength
Web lashing	70% of breaking strength
Wire rope (single use)	80% of breaking strength
Wire rope (re-useable)	30% of breaking strength
Steel band (single use)	70% of breaking strength
Chains	50% of breaking strength
lumber	0.3 kN per cm² normal to the grain

Table: Determining the MSL from the breaking load

Lashing elements and lashing materials *There are no international standards on tie down lashings. It is to be expected, however, that manufacturers or dealers will provide information on or certification of the nominal breaking load on purchase. It is, however, generally unclear how this value was determined and under what conditions it is valid. No reference is made to any other properties, such as elasticity and fatigue strength.*

The table below provides a list of the most important materials and elements with the usual characteristic values. An accepted rule of thumb is used for the breaking load.

If millimeters are chosen instead of centimeters for the dimensions, the breaking load values will be in decanewtons [daN] instead of kilonewtons.

Material/element	***Breaking load [kN]***	***Notes***
Natural fiber ropes (manila, sisal, hemp)	*6 x d²*	*d = diameter of rope in cm. Natural fiber ropes are sensitive to decay, acids and alkalis. All fiber ropes are sensitive to chafing from sharp edges. Knots on synthetic fiber ropes can slip open. Heavers of sufficient thickness should be used to tighten them and these in turn should be secured to prevent them from unwinding.*
Polypropylene	*12 x d²*	
Polyester	*15 x d²*	
Polyamide	*20 x d²*	
Hercules (sisal)	*6 x d²*	
Hercules (polypropylene)	*12 x d²*	

Material/element	***Breaking load [kN]***	***Notes***
Wire rope 6 x 9 + 1 FC *Wire rope 6 x 19 + 1 FC* *Wire rope 6 x 37 + 1 FC*	*50 x d²*	*d = diameter of rope in cm. Producing conventional wire rope lashings with turnbuckles and rope clips is technically demanding and can give rise to a number of potential problems. More detailed notes are provided after this table.*
Wire rope 6 x 9 +7 FC *Wire rope 6 x 12 +7 FC* *Wire rope 6 x 15 +7 FC*	*25 x d²*	

Material/element	Breaking load [kN]	Notes
Shackles	20 x d^2	d = diameter of bolt in cm. The breaking load formula only applies to shackles made of standard strength steel.
Turnbuckles	20 x d^2	d = diameter of thread in cm. The breaking load formula only applies to turnbuckles made of standard strength steel.

Material/element	Breaking load [kN]	Notes
Untreated steel strap Blued steel strap	70 x w x t 85 x w x t	w = width of strap in cm t = thickness of strap in cm.

Material/element	Breaking load [kN]	Notes
Long- and short-link chains with different tensioners	See manufacturer's specifications	Tie down lashing chains are always made of higher strength steel to save weight. Calculation of the breaking load is therefore dependent on the manufacturer's specifications.

Material/element	Breaking load [kN]	Notes
Deck eyes and eye plates	20 x d^2	d = diameter of eye material in cm. The breaking load formula only applies to material made of standard strength steel.

Material/element	Breaking load [kN]	Notes
Synthetic fiber lashing belts	See manufacturer's specifications	Lashing belts are produced in a number of different grades. They are highly elastic but can become permanently deformed when subjected to threshold stresses greater than 50% of the breaking load and therefore quickly become loose. They must not be knotted. They are sensitive to external influences in the same way as synthetic fiber ropes.

Material/element	Breaking load [kN]	Notes
Weld joints subjected to shear loads	MSL = 4 kN per cm	Single-layer weld, 4 mm thick.
	MSL = 10 kN per cm	Three-layer weld, 10 mm thick.

Material/element	Breaking load [kN]	Notes
Softwood used for bracing	MSL = 0.3 kN per cm^2	Compressive load perpendicular to the grain
Softwood used for bracing	MSL = 1 kN per cm^2	Compressive load parallel to the grain

Material/element	Breaking load [kN]	Notes
Special equipment for ro/ro ships	-	Trailer horses, trailer jacks, wheel chocks; breaking loads usually unknown
Special equipment for container ships	See manufacturer's specifications	Lashing rods, turnbuckles, twist locks, D rings, sockets, bridge fittings, tie plates, etc. Strength and material properties as per the requirements of the relevant classification society

For economic reasons, it is advisable to try to homogenize load securing equipment and load securing arrangements.

***Homogeneous load securing equipment** comprises elements which where possible have the same MSL values.*

*A **homogeneous load securing arrangement** comprises load securing equipment which are arranged in such a way that, when subjected to extreme loads, they bear the part of the load appropriate to their strength.*

To summarize the problems of load securing, some examples are provided below as a sort of "recipe" how to calculate the number of securing devices required, what such a device can withstand and what can be expected of it.

Example: Tie-down lashing:

Use of tie down lashings

Let us assume that the wooden case on the flatrack has a weight of 12,000 daN. Without taking into account the risk of this overheight case tipping, the package must be secured for overseas shipment. Lateral acceleration forces of 0.8 g can be expected. This means that lateral forces of 12,000 daN x 0.8 or 120 kN x 0.8 i.e. 9,600 daN or 96 kN can be expected.

The single-use webbing belts used in the figure on the left have a breaking load of 3,433 daN. This equates to 2,403 daN at an MSL no greater than 70% of the breaking load. No more than half of this, i.e. around 1,200 daN, may be used as the pretensioning force. It should be noted that in practice this value can neither be achieved nor maintained throughout the entire voyage.

The effective length of the belt from its attachment to the lashing point to the edge of the case (red line) is 3.0 m. The effective height (green line) is 2.93 m, a very high vertical component (97.6%). This component can be determined for any load by dividing the effective height by the effective length. Multiplying this by the pretensioning force gives the force with which the tensioned side of the load is pulled onto the flat. In the example, this is 97.6% of 1,200 daN, or 1,171 daN. If we assume ideal conditions and this force were completely transmitted to the other side, a total pretensioning force of 2,342 daN per lashing can be assumed. Assuming a friction coefficient of 0.3, a single tie-down lashing can achieve a securing force of around 703 daN. 13.65 belts are theoretically required to secure the case (9,600 daN/703 daN). In reality, the webbing belts used would be able to maintain a maximum pretensioning force of around 100 daN through 200 daN during the voyage. This means that a single belt is able to maintain a long-term securing force of 30 daN through 60 daN. To have really "secured" the case, somewhere between 160 and 320 belts would have to be provided!!!

Note: Tie down lashings only provide securing forces of the vertical component of the pretensioning force multiplied by the friction coefficient.

Note: The pretensioning force must never be greater than 50% of the MSL of the weakest securing element.

This recipe is simpler and more precise than a calculation which uses the lashing angle α, since in practice distances are easier to measure than angles. If the vertical component of a lashing is to be calculated using the lashing angle, the permissible lashing force must be multiplied by the sine of the lashing angle: vertical component = MSL x sin α.

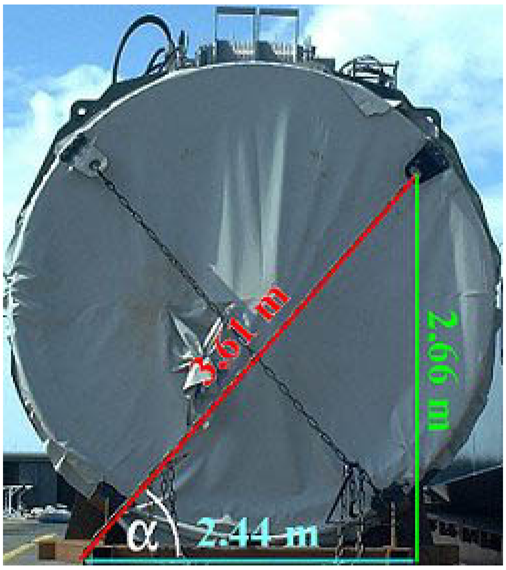
The smaller the lashing angle, the smaller the vertical component will be. At a lashing angle of 90° it will be 100% (sin 90 ° = 1), at 75° 97% (sin 75 ° = 0.9659), at 60° 87 % (sin 60 ° = 0.866), at 45° 71% (sin 45 ° = 0.7071), at 30° 50% (sin 30 ° = 0.5), at 15° 26% (sin 15 ° = 0.2588) and at 0° 0% (sin 0° = 0).

Example: Direct lashing:

The main difference between direct lashings and tie-down lashings is that with direct lashings, the pretensioning force can and should be kept as low as possible.

Note: The pretensioning force should be as low as possible on direct lashings. However, slack must never be able to develop in lashings.

The pretensioning force must, however, be sufficiently high to prevent a lashing from becoming slack. The reason for this is that the lashing may be loaded up to its MSL under stress and the vertical components resulting from this produce additional frictional forces.



Direct lashing with chains

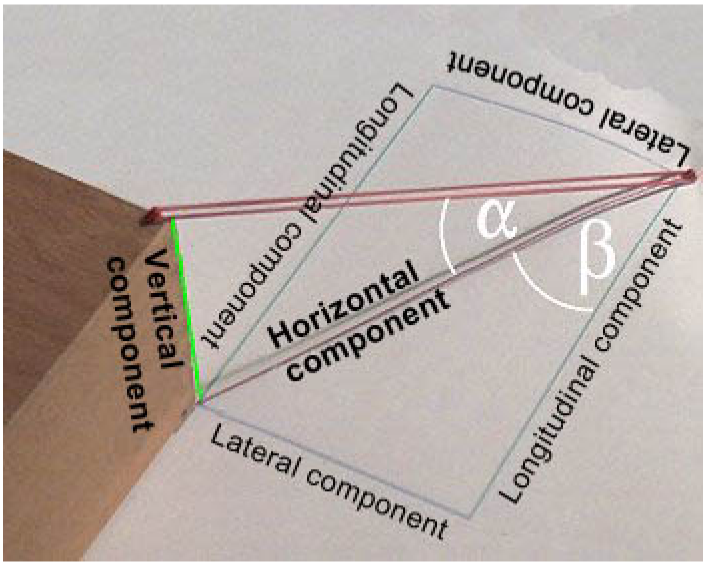
For those who enjoy mathematics, the relevant lashing forces can be calculated by first measuring the lashing angle α (47.5°) and then the sine and cosine of this angle to determine the vertical and horizontal components and using these in conjunction with the permissible lashing force of the chain.

Using another recipe, it is unnecessary to determine this angle or its sine and cosine. Basic arithmetic will suffice. The following lengths are determined by using a tape measure or meter rule: the effective length of the lashing chain (red line = 3.61 m), the effective vertical component (green line = 2.66 m) and the effective horizontal component (blue line = 2.44 m). Using rules of thumb or the manufacturer's specifications, the breaking load and the MSL of the 13 mm link material diameter high-tensile chain. This corresponds to 10,000 daN. Checking the size of the lashing point gives a steel diameter of 28.3 mm. This gives a breaking strength of 16,000 daN and an MSL of 8,000 daN. This value represents an upper threshold if the chain components have a higher MSL.

Vertical securing force: 2.66 m : 3.61 m x 10,000 daN = 7,368 daN. A lashing chain secures the package against vertical movement with a force of 7,368 daN. But this is not so important. This force becomes effective when the package is moved horizontally causing the chain to be tightened; the package is then pulled toward the floor with this force. Assuming a sliding friction coefficient of 30% ($\mu = 0.3$), the package is secured by a lashing in all directions with a force of 7,368 daN x 0.3 = 2,210 daN.

Shortfall in securing force: 2.44 m / 3.61 m x 10,000 daN = 6,759 daN. A lashing chain directly secures the package laterally with 6,759 daN. To this are added the frictional securing forces of 2,210 daN as previously determined. The calculated chain lashing secures the machine component against movement laterally towards the right with a force of 8,969 daN.

Since no longitudinal components exist, a chain only secures the machine component longitudinally with the frictional forces produced by the vertical component of 2,210 daN.



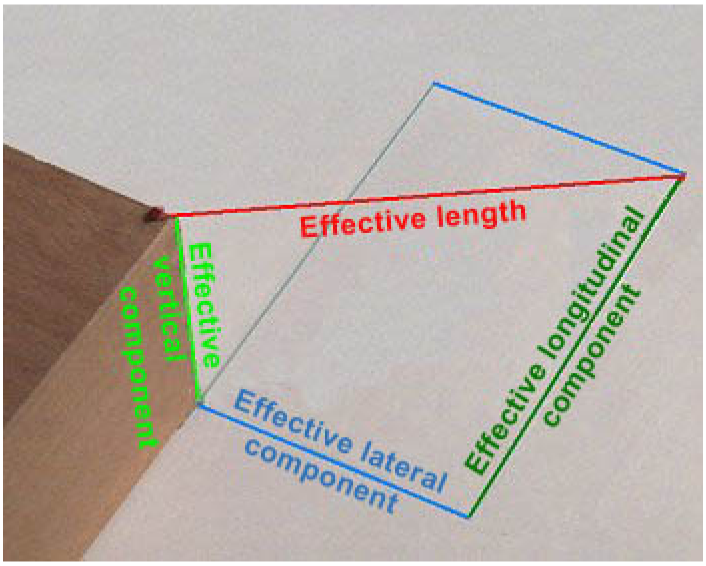
Different components on a diagonal lashing with lashing angles

To calculate the longitudinal, transverse and vertical securing forces using the lashing angles α and β, use the following method:

Component	Calculation
Vertical component	MSL x sin α
Horizontal component	MSL x cos α
Additional frictional forces	Vertical component x μ or MSL x sin α x μ
Pure lateral component	Horizontal component x sin β or MSL x cos α x sin β
Pure longitudinal component	Horizontal component x cos β or MSL x cos α x cos β

Since the additional frictional forces produced by the vertical component may be added to the forces produced by the lateral and longitudinal components, the securing forces produced are:

Securing forces	Calculation
Vertical securing	MSL x sin α
Lateral securing	MSL x cos α x sin β + MSL x sin α x μ
Longitudinal securing	MSL x cos α x cos β + MSL x sin α x μ



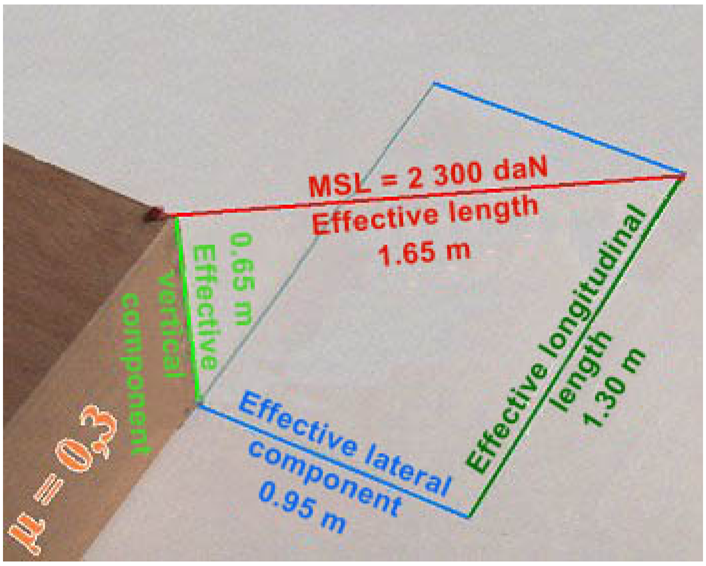
Determining the securing forces

Again, a recipe is quicker, simpler and more precise. Four distances must be measured and the MSL of the weakest load securing element must be determined. The friction coefficient must be determined or estimated.

Securing forces	Calculation
Vertical securing	Effective vertical component / effective length x MSL
Additional frictional forces	Effective vertical component / effective length x MSL x µ
Lateral securing including additional frictional forces	Effective lateral component / effective length x MSL + effective vertical component / effective length x MSL x µ
Longitudinal securing including additional frictional forces	Effective longitudinal component / effective length x MSL + effective vertical component / effective length x MSL x µ

Calculated example:

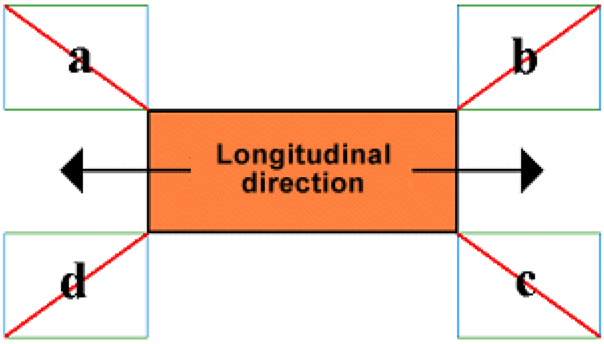
A doubled, single-use webbing belt is used for securing as previously. For reasons of caution, the MSL is not assumed to be 70% but only 30% of the breaking load. The sketch below shows all the data needed.



Calculated example: Determining the securing forces

Securing forces	Calculation
Vertical securing	0.65 m / 1.65 m x 2,300 daN = 906 daN.
Additional frictional forces	0.65 m / 1.65 m x 2,300 daN = 906 daN x 0.3 = 271.8 daN
Lateral securing including additional frictional forces	0.95 m / 1.65 m x 2,300 daN = 1,324 daN + 271.8 daN = 1,595.8 daN
Longitudinal securing including additional frictional forces	1.30 m / 1.65 m x 2,300 daN = 1,812 daN + 271.8 daN = 2,083.8 daN

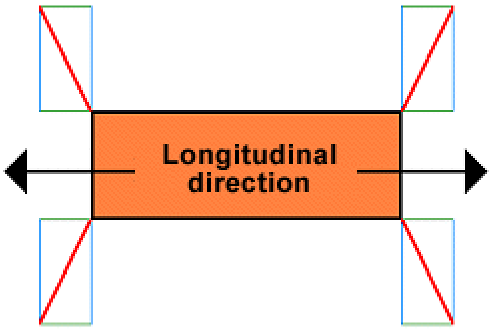
As far as the overall securing is concerned, it should always be borne in mind what lashings are subjected to loads under what circumstances:



Package secured with four diagonal direct lashings

Upward	4 x vertical securing = 4 x 906 daN	3,624 daN
Longitudinally, to the left	The longitudinal components of b and c restrain	4,167.6 daN
Longitudinally, to the right	The longitudinal components of a and d restrain	4,167.6 daN
Laterally, upward	The lateral components of d and d restrain	3,191.6 daN
Laterally, downward	The lateral components of a and b restrain	3,191.6 daN

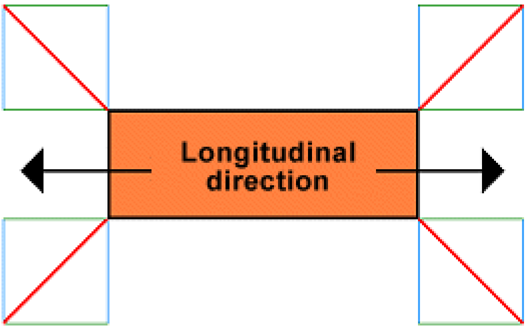
It can be concluded that the lashing arrangement would not be not homogeneous if the load in the example were loaded on a flatrack transported using fore and aft stowage on a container ship, where acceleration forces of 0.4 g occur longitudinally and acceleration forces of 0.8 g occur laterally. In this instance, the lashings would need to have been arranged so that the lateral component was twice the size of the longitudinal component:



Lateral components twice as large as longitudinal components

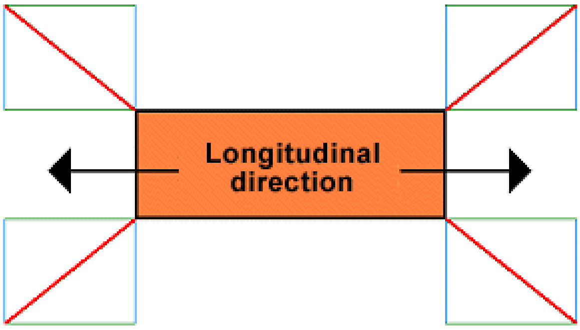
If it is assumed that the flatrack is transported using fore and aft stowage on a container ship and transported during precarriage and/or onward carriage on a road vehicle, longitudinal and transverse acceleration forces of 0.8 g should be assumed for the lashings.

The decision in this instance is simple: both components must be the same size.



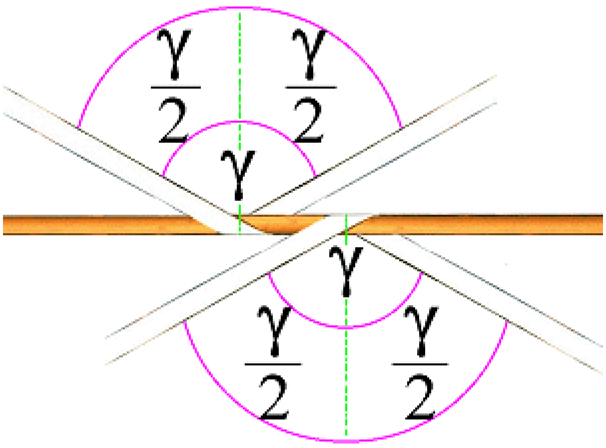
Transverse and longitudinal components same size

If the flatrack is transported during precarriage or onward transport on a freight car in multimodal operations, longitudinal acceleration forces of 1 g are assumed. If lateral acceleration forces of 0.8 g are assumed, the longitudinal components must be 25% larger than the lateral components or the lateral components can be 20% smaller than the longitudinal components:



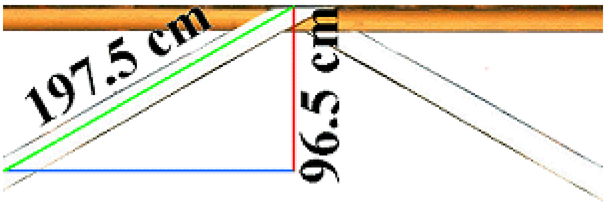
Longitudinal components 25% larger than lateral components

Using tie-down lashings also produces angles which cause a reduction in the MSL. The effects are not very dramatic because they are the cosine of half the opening angle between the ends of the lashing. It does not really matter whether angles are measured and forces are calculated or lengths are measured. It is easier for people familiar with mathematics to calculate using the trigonometric function than to measure distances - provided a pocket calculator with trigonometric functions or a relevant table is available. Both methods are feasible. Anyone who is familiar with a the shape of a cosine wave or has certain values in their head, can also make a good estimate.



Angle which is too large to be permitted

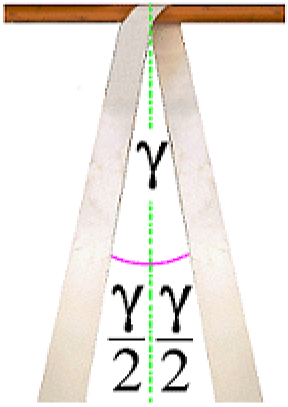
The angle γ is 121.552°, but who can ever determine an angle as precisely as this? Half this angle is 60.776°. The cosine of this angle is 0.488. This makes it obvious that this type of securing is ineffectual. The mathematically calculated part only generates securing forces which are less than half. It would have been better to have secured the cargo with a single-strand direct lashing. The cosine of 60° is 0.5. It is therefore clear that lashings are only worthwhile if their opening angle - i.e. the complete γ - is significantly less than 120° and γ/2, significantly less than 60°. The same could have been determined - possibly more quickly - by taking measurements:



As previously: Angle which is too large to be permitted

The effective length of one end of the lashing is 197.5 cm, the effective lateral dimension is 96.5 cm. This is less than half. Both ends of the lashing together are thus less than 1. It can also be seen and proved from this that this lashing is not worthwhile.

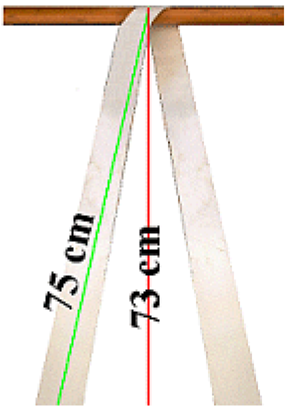
This does not apply here:
The opening angle here is γ 27° (γ/2 is thus 13.5°). The cosine of 13.5° is 0.973 - i.e. close to 1. This means that this securing aid achieves nearly double the MSL, or to be precise 1 times the MSL of a single strand.



Angle used for tie-down lashings in practice

Measuring would have produced approximately the same results:

If - using our recipe - the smaller measured value is divided by the larger measured value, the result is 0.973. That means, the lashing secures 2 x 0.973 times, i.e. 1.946 times the MSL of a single strand.



As previously: Angle used for tie-down lashings in practice

To be precise, the angle between the ends must be measured in 3D space, since lashings which are attached to separate lashing points form an "oblique" angle to each other. These problems should not occur during measuring, even if one end comes from the top and the other end comes from the bottom.

Here are the rough guideline values for the MSL at different estimated angles:

Estimated angle	MSL of the lashing
120°	2 x MSL of a single strand x 0.50 = 1.0 x MSL of a single strand
90°	2 x MSL of a single strand x 0.70 = 1.4 x MSL of a single strand
60°	2 x MSL of a single strand x 0.87 = 1.7 x MSL of a single strand
40°	2 x MSL of a single strand x 0.92 = 1.8 x MSL of a single strand
30°	2 x MSL of a single strand x 0.97 = 1.9 x MSL of a single strand
< 30°	2 x MSL of a single strand x 1.00 = 2.0 x MSL of a single strand

4.4.1 Lashing materials

4.4.1.1 Lashing materials, Part 1

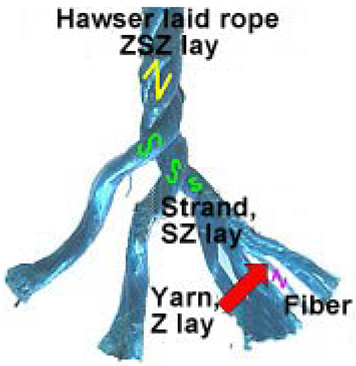
The term "ropes" covers a wide range of manufactured ropes made of different materials for different purposes. In the field packing and load securing, a distinction is made between:

- Fiber ropes
- Wire ropes and
- Composite or mixed ropes

Fiber ropes are divided into:

- Natural fiber ropes and
- Synthetic or man-made fiber ropes

Natural fiber rope



Split fiber rope made of polypropylene

Ropes are made in a number of different ways. Generally, a distinction is made between laid rope and braided rope. In many cases, the way a rope is manufactured determines how it is treated and used. The basic process used to manufacture laid fiber ropes is as follows: When they have been obtained from the raw materials, the fibers are combed to separate them. These are then twisted to produce yarns. In the trade, this is known as laying. If the direction of lay is to the right, it is known as Z-laid, or if it is to the left, it is known as S-laid. In the next stages of the process, the directions of lay are alternated. This is referred to as a 'cross lay' or 'conventional lay'. A cable lay is only used for very strong fiber ropes - but this is not relevant for load securing purposes: In the normal direction of lay, three Z-laid ropes are laid to the left to produce a cable; in the opposite direction of lay, three S-laid ropes are laid to the right to produce the finished cable. The normal direction of lay is also known as Z-lay or ZSZS-lay in and the opposite direction of lay is known as S-lay or SZSZ-lay.

Natural and synthetic fiber ropes - all hawser-laid and Z-laid

Laid (twisted) ropes are generally used for load securing purposes.

They are generally type A hawser-laid, i.e. a 3-strand rope is used. There are both Z-laid and S-laid versions of this type. The normal direction of lay, however, is to the right.

Natural fiber ropes are no longer used for load securing in most industrialized countries. In some countries, however, natural fiber ropes may be used for securing loads in or on specific cargo transport units. This includes in particular ropes of the following materials:

- Hemp (Ha)
- Manila (Ma)
- Sisal (Si)
- Manila mixed (Ma/Si)

Natural fiber ropes are very sensitive to acids, alkalis and solvents. Mold and other microorganisms attack the fibers. Manila and sisal are comparatively resistant to natural weathering, but hemp loses its strength very quickly unless it is impregnated. As impregnated ropes usually have a strong odor, they must not be used for odor-absorbent or odor-sensitive cargoes. Natural fibers swell when they absorb moisture and shrink on drying. Fluctuations in moisture content result in considerable changes in the length of ropes:

- The ropes become shorter when wet;
- The ropes become longer when dry.

For the above reasons, it is very difficult to maintain uniform tension in the ropes. Their range of application is therefore limited to use in closed cargo transport units where no great fluctuations in humidity are to be feared. Natural fiber ropes are also combustible and can lead to spontaneous combustion in connection with certain chemicals. One advantage is thst natural fiber ropes are "environmentally friendly". Since they decay quickly, they can be disposed of without any problems.

The main raw materials for synthetic fiber ropes are:

- Polyester (PES)
- Polyamide (PA)
- Polypropylene (PP)
- Polyethylene (PE)
- Hempex

Polyester exhibits exceptionally good behavior with acids, alkalis and solvents and also only loses very little strength due to natural weathering; it is therefore very UV-stable. Polyester ropes are not purchased for load securing purposes, however, as they are relatively expensive.

Polyamide (generally known under its trade names nylon, perlon etc.) exhibits good behavior with alkalis and solvents but is sensitive to acids. It loses around 20% of its strength per year from natural weathering, especially UV radiation. Because of its price, polyamide is rarely used for load securing purposes.

Polyethylene has no place in load securing on account of its poor mechanical properties. It is even banned for use as slinging ropes.

Hempex is a modified polypropylene material which looks so similar to the natural fiber hemp that it is often confused with it. It is UV-resistant but in terms of its strength not much better than natural fiber ropes. As it is particularly soft, it is sometimes used to fasten tarpaulins etc.

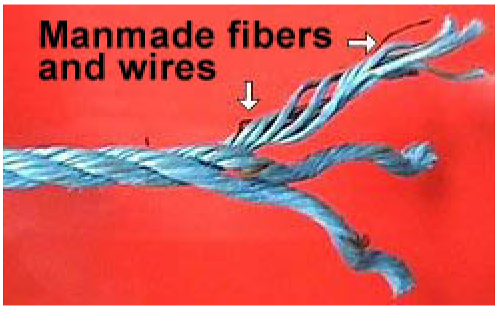
Polypropylene exhibits very good resistance against acids, alkalis and solvents. If it is not stabilized, however, it is very sensitive to natural weathering. For this reason, polypropylene ropes should always be light and heat stabilized. Black dyed ropes are best suited for this. Their strength only decreases at around 5% per year from natural weathering.

There are two main groups of polypropylene ropes:

- monofilament ropes and
- multifilament fiber ropes.

Monofilament ropes behave exceptionally well under dynamic strain, but because of their material properties are difficult to knot. Knots tend to come undone. Monofilament ropes are thus almost exclusively used as slinging ropes. They are stronger than a steel-reinforced "Hercules", but it is not to be recommended that they be purchased as load securing material.

Multifilament ropes exhibit very negative properties when they are dynamically stressed. Movement causes the fibers to separate further, which quickly produces a rupture. This type of stress rarely occurs with load securing. For this reason, composite ropes are produced for load securing purposes generally use multifilament materials.



Steel-reinforced "Hercules" lashing rope

The type of composite rope generally used for lashing purposes is known as "Hercules". This is a rope made of steel wire and natural or synthetic yarns.

Predominantly, "Hercules" made of interwoven polypropylene and wires is sold as lashing material. Ropes of interwoven wire and sisal are no longer commonly used in most industrial countries. "Hercules" has the same strength for lashing purposes as ropes made of sisal or polypropylene with the same diameter, because the wire in Hercules does not have a load-bearing function. The individual wrapped wires have a very low strength and are only intended to increase the rigidity of the material and improve its twisting properties, e.g. when tightening it with a Spanish windlass. The main advantage of "Hercules" over fiber ropes is not its strength but improved handling. In terms of its pure material properties, the same applies as for sisal or polypropylene. It must be stressed again that it exhibits good properties in terms of resistance to aggressive substances.

Thin ropes for securing tarpaulins

Car secured with "Hercules" lashing

Fiber ropes are suitable for securing tarpaulins and relatively light loads, e.g.

- Automobiles in or on containers
- Drum cargoes, fiber drums and similar loads in small batches and light receptacles
- Fairly light cases, small batches of boxed goods, individual pallets etc.

5 mm thick polypropylene rope for securing tarpaulins etc.

The MSL (Maximum Securing Load) of fiber ropes is 33% of the breaking load. Since the breaking load of polypropylene can be calculated with a rule of thumb using the formula 12 x d^2, the MSL for the rope shown is 1 kN or 100 daN, depending whether the diameter was specified in centimeters or millimeters.

Calculating the diameter of a polypropylene strap: 5 mm

Breaking load	MSL factor	MSL	
0.5 x 0.5 x 12 = 3 kN	x 0.33 =	1 kN	(diameter in cm)
5 x 5 x 12 = 300 daN	x 0.33 =	100 daN	(diameter in mm)

Since a factor of 33% is corresponds to virtually one third, the MSL can also be calculated directly with an easily remembered formula:

MSL of polypropylene ropes = d x d x 4

If a strap or rope is doubled, the values can also be doubled; if it is used four-fold, the values can be quadrupled. It is not possible to increase the values any further, since there is no guarantee that all the runs of rope would be evenly loaded.

Determining the diameter of polypropylene-covered "Hercules": 12 mm

Breaking load	MSL factor	MSL	
1.2 x 1.2 x 12 = 17.28 kN	x 0.33 =	5.76 kN	(diameter in cm)
12 x 12 x 12 = 1,728 daN	x 0.33 =	576 daN	(diameter in mm)

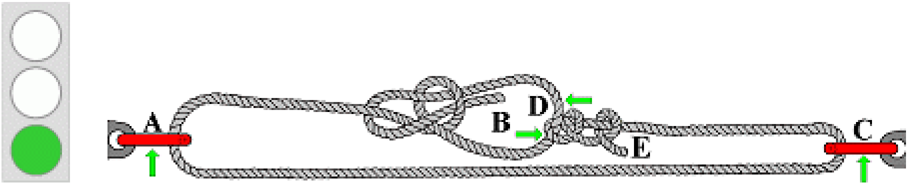
It would be rather quicker to calculate this using the direct rule of thumb for the MSL:

MSL PP "Hercules" 1.2 cm thick = 1.2 x 1.2 x 4 = 5.76 kN

MSL PP "Hercules" 12 mm thick = 12 x 12 x 4 = 576 daN

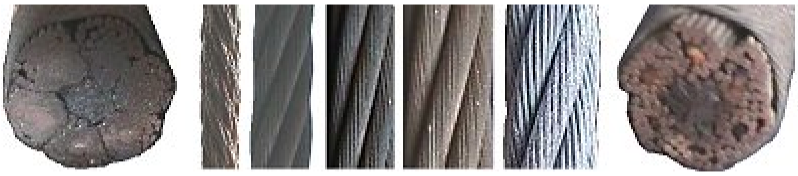
In this case as well, the values can be doubled or quadrupled respectively for double or (at the most) four-fold use.

Safety note: Fiber ropes must never be tightened over sharp edges!



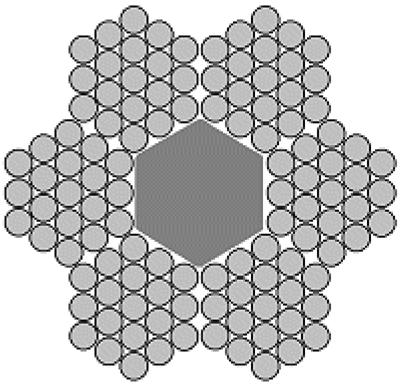
To fabricate a direct lashing with a "Hercules" rope of this type, the necessary rope length is estimated and cut off. The end is threaded through one of the lashing points (A). A loop (B) is knotted into one of the ends using a bowline. The other end is threaded through the second lashing point at (C). The loose end is threaded through the loop of the bowline at (D) and pretensioned by hand. The end is knotted at (E) with at least two half hitches. If greater pretensioning forces are required than those which can be achieved manually, this can be achieved using a Spanish windlass - i.e. using heavers.

If a strap or rope is doubled, the values can also be doubled; if it is used four-fold, the values can be quadrupled. It is not possible to increase the values any further, since there is no guarantee that all the runs of rope would be evenly loaded.

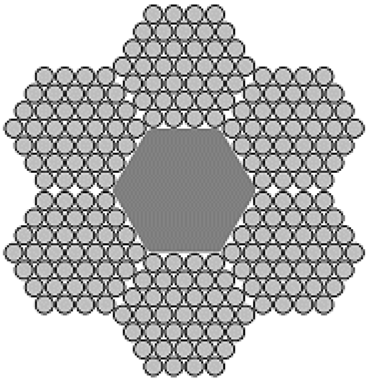


Different rope structures - cross-sections and plan views

The type of steel wire ropes mainly used for lashing are cross-laid stranded ropes laid to the right. Occasionally, left-handed cross-lay used.



6 x 19 + 1 FC



6 x 37 + 1 FC

Stranded rope is the designation for a wire rope construction where the individual wires are laid into strands and these are in turn laid into the finished product. The number of individual wires and strands significantly influences the pliability of the wire and its price. The more individual wires there are in a wire rope, the more flexible but also the more expensive it is. A frequently used construction consists of 6 strands each with 19 individual wires per strand, with a fiber core to fill the cavity remaining in the center. The fill factor for rope constructions of this kind is around 0.455, i.e. the cross-sectional area occupied by metal accounts for around 45.5% of the total cross-section. Wire ropes with the construction 6 x 37 + 1 FC are also favored. These have the same fill factor.

Determining the diameter of a steel wire rope: 16 mm

Using a rule of thumb, the breaking load and MSL of single-use wire ropes can be calculated as follows:

Breaking load	MSL factor	MSL	
1.6 x 1.6 x 50 = 128 kN	x 0.80 =	102.4 kN	(diameter in cm)
16 x 16 x 50 = 12,800 daN	x 0.80 =	10,240 daN	(diameter in mm)

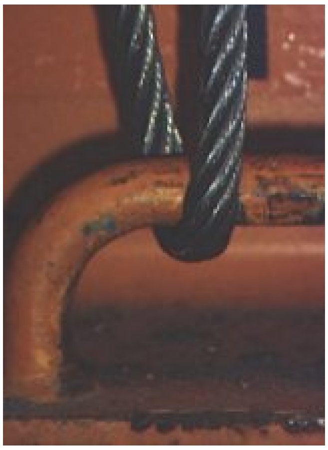
Since the of 80% of 50 equates to a value of 40, the MSL can also be calculated directly with an easily remembered formula:

MSL single-use steel wire ropes of the above type = d x d x 40

It would be a little quicker to calculate the MSL using the direct rule of thumb:

MSL for steel wire rope, 1.6 cm thick = 1.6 x 1.6 x 40 = 102.4 kN

MSL for steel wire, 16 mm thick = 16 x 16 x 40 = 10,240 daN



Use of a 16 mm-thick steel wire rope on a platform container

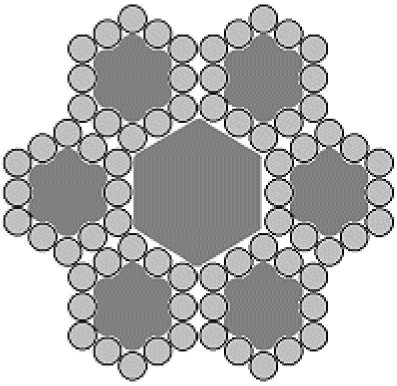
Using steel ropes of this kind is a waste of materials, since the high MSL value is out of proportion to that of the lashing points on the containers. The strongest lashing rings have an MSL value of 8,000 daN, many are around 5,000 daN and most are around 3,000 - 4,000 daN. To for homogeneous lashings, it is usually perfectly sufficient to use wire ropes of a smaller diameter. For instance, 12 mm wires:

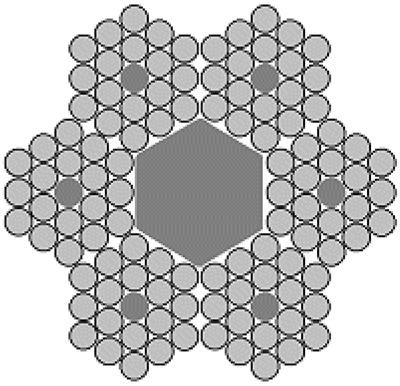
MSL for steel wire rope, 1.2 cm thick = 1.2 x 1.2 x 40 = 5.76 kN

MSL for steel wire, 12 mm thick = 12 x 12 x 40 = 5,760 daN

Different MSL values must be applied for reusable wire ropes. Wires of this kind must only be calculated with 30% of the breaking load for the MSL:

Breaking load	MSL factor	MSL	
1.6 x 1.6 x 50 = 128 kN	x 0.30 =	38.4 kN	(diameter in cm)
16 x 16 x 50 = 12,800 daN	x 0.30 =	3,840 daN	(diameter in mm)





6 x 12 +7 FC **6 x 18 +7 FC**

Significantly lower fill factors are exhibited by wire ropes with constructions such as 6 x 9 + 7 FC, 6 x 12 + 7 FC, 6 x 15 + 7 FC, 6 x 18 + 7 FC or similar, where, as the designation already indicates, a fiber filler has been incorporated in the center of each strand. Ropes of this kind are frequently used by Dutch and Belgian companies as lashing wires.

The breaking loads and MSLs of wires of this kind are only half as high, because a factor of 25 rather than a factor of 50 has to be used for calculation.

Breaking load	MSL factor	MSL	
d x d x 25	x 0.80 =	kN	(diameter in cm)
d x d x 25	x 0.80 =	daN	(diameter in mm)

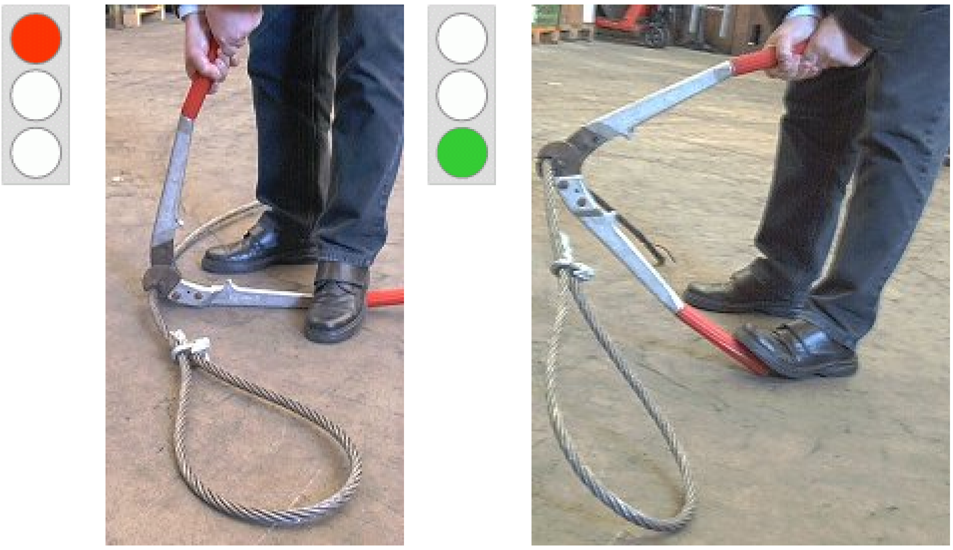
The same applies for re-usable wire ropes of this type:

Breaking load	MSL factor	MSL	
d x d x 25	x 0.30 =	kN	(diameter in cm)
d x d x 25	x 0.30 =	daN	(diameter in mm)

Steel wire rope coil

When ordering wire ropes, the following details should be stipulated to ensure that the correct rope type will be received:

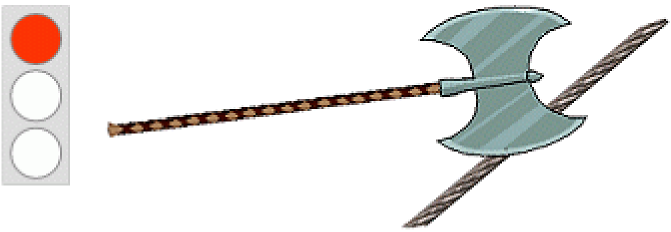
-	Diameter in mm or inches	e.g. 16 mm or 5/8"
-	Quantity and length	e.g. 20 x 200 m
-	Rope construction	e.g. 6 x 19 + 1 FE
-	Type and direction of lay	e.g. cross lay, to the right
-	Special features (plain, galvanized etc.)	e.g. plain
-	Nominal strength	e.g. 1570 N/mm²
-	Greasing	e.g. normal
-	Termination: swaged / sharpened	e.g. swaged
-	Packaging	e.g. coils



Cutting wire ropes with shears

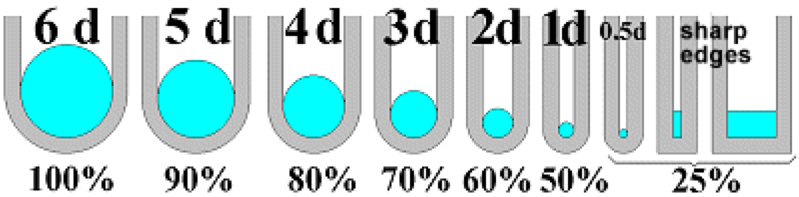
Incorrect - small lever arm	**Correct - large lever arm**

Wire ropes can be cut to length with hydraulic shears or other special tools if larger quantities need to be processed. Handshears are sufficient on site and with small quantities.



Wires can be damaged by sharp edges.

Running wires around sharp edges will lower their MSL. There are precise values, but a number of additional factors should be taken into account. Rough but nonetheless usable values are provided in this easily remembered table:



MSL of a single run at various bending angles

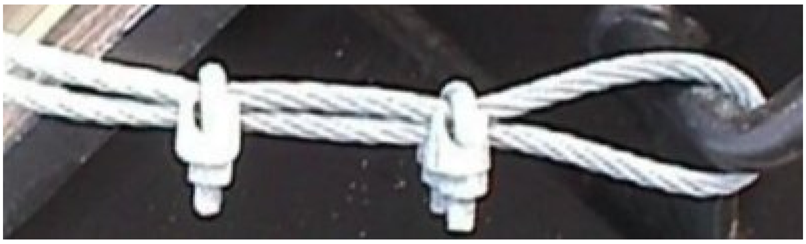
You will find an example showing exact values in Volume II.


Wire ropes with spliced or pressed eyes are rarely used for lashing. Generally, wire cable clamps (clips) are used to connect to other lashing elements, such as turnbuckles, shackles, lashing rings etc. There are suitable clips available for every thickness of rope, in both metric and Imperial sizes. For a 12 mm wire, 12 mm or ½" clips are required. For 16 mm wires, 16 mm or 5/8" clips must be provided.

When the nuts are correctly tightened as described further below, the following figures can be seen as guideline values for the strength of wire cable clips with common rope diameters.

At a sufficient tightening torque:
1 clip = 25% MSL

Up to 25% of the MSL can be achieved with one clip. If - as in this case - there is no tightening torque, the value approaches 0.



At a sufficient tightening torque: 2 clips = 50% MSL

50% of the MSL of the wire rope is achieved using two wire cable clips. The indentations in the wire indicate a good tightening torque. The following rule of thumb applies: if the free end on which the U-bolts of the wire cable clips should be placed is crushed to half the thickness of the wire, the clips have been tightened to a sufficient torque.

Only with a sufficient tightening torque and correctly attached clips:
3 clips = 75% MSL

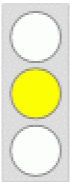
The wire cable clips have been attached incorrectly and the tightening torques are too low. The MSL of lashings of this kind is usually overestimated. An maximum MSL of approximately 75% can be achieved with three wire cable clips.

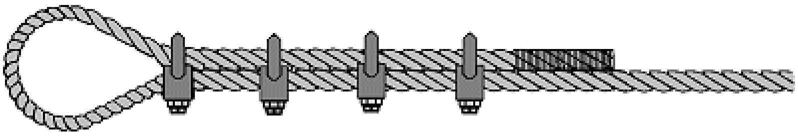
Incorrectly attached wire cable clips in insufficient quantity

All too often in practice, too few wire cable clips are used or they are attached incorrectly. Often, the nuts are not tightened sufficiently. The wires slip through the wire cable clips under load.

Wires which have slipped through where only two wire cable clips were attached

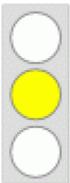
If a wire rope lashing is to be homogeneous, four wire cable clips must be placed with the U-bolt on the free end.:

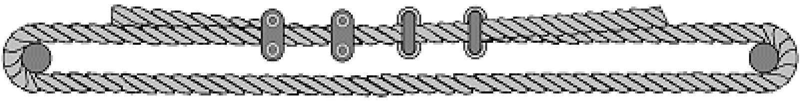




Single cable with eye

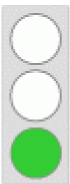
This type of attachment is advisable if relatively long lashings have to be made. They are usually not necessary for container loads.

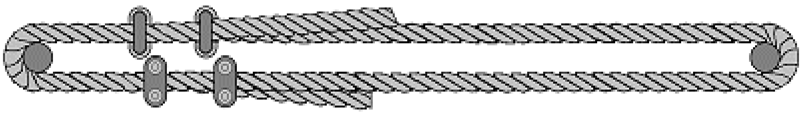




Sling or double run - unsuitable construction

This construction is often used for shorter lashings. But it should not be made like this.

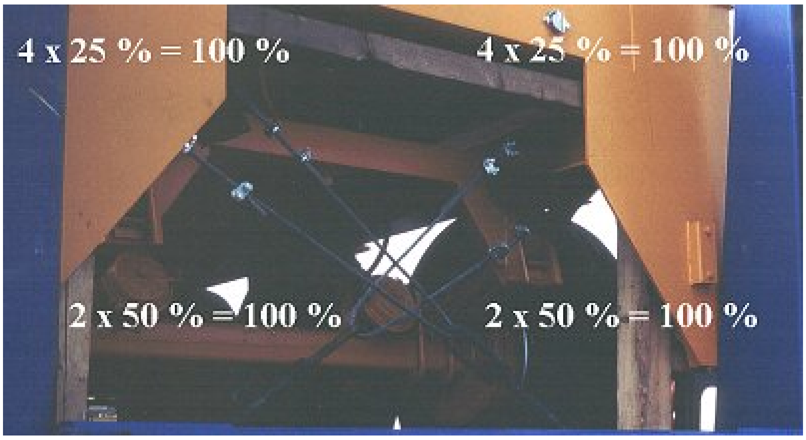




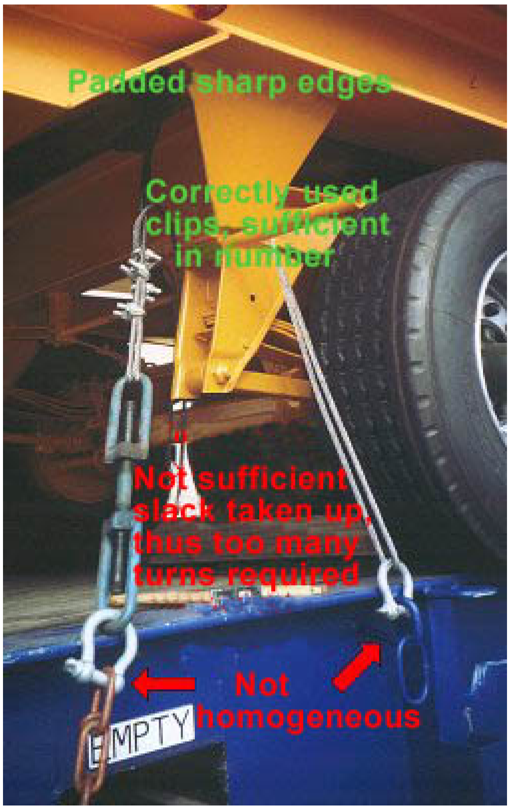
Sling or double run - ideal construction

This format should always be used for relatively short lashings because it is the most resilient. Inadequacies such as the presence of sharp edges can also be counteracted with this method.

Where possible, work should be carried out as demonstrated here.



Positive example - wire rope arranged correctly, wire cable clips attached correctly and sufficiently high tightening torque on the nuts



Lashing is a technically demanding task which has to be learnt. Otherwise, errors creep in even with the best will in the world.

Lashing which is not homogeneous

Anchor shackle

Chain shackle

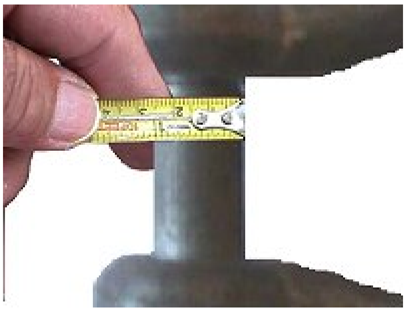
Anchor shackles should be preferred for use as lashing shackles. They can adapt better to the directions in which forces arise.

Using a rule of thumb, the breaking load and MSL of lashing shackles can be calculated as follows:

Breaking load	MSL factor	MSL	
d x d x 20	x 0.50 =	kN	(diameter in cm)
d x d x 20	x 0.50 =	daN	(diameter in mm)

Since the factor 50% of 20 is equivalent to 10, the MSL can also be calculated directly with an easy-to-remember formula:

MSL for lashing shackle = d x d x 10



Determining the diameter of a bolt on a lashing shackle: 26 mm

The diameter of the bolt is first measured in centimeters or millimeters. The breaking load formula only applies to shackles made of standard strength steel. The value for this shackle is quickly calculated using the direct rule of thumb for the MSL.

MSL for lashing shackle bolt of diameter 2.6 cm = 2.6 x 2.6 x 10 = 67.6 kN

MSL for lashing shackle bolt of diameter 26 mm = 26 x 26 x 10 = 6,760 daN

Lashing turnbuckle with very well worked weld seams

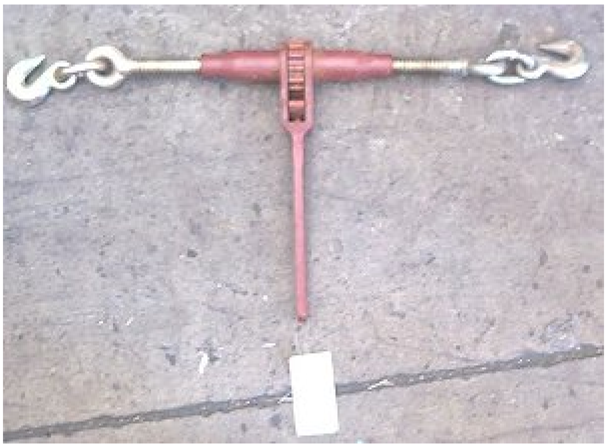
The same values apply to turnbuckles as to lashing shackles. The diameter of the thread is first measured in centimeters or millimeters. The breaking load formula only applies to turnbuckles made of standard strength steel. The value for this turnbuckle is quickly calculated using the direct rule of thumb for the MSL, if the thread was measured at 1 1/8 inch = 28.575 mm.

MSL for lashing turnbuckle of thread diameter 2.86 cm
= 2.86 x 2.86 x 10 = 81.796 kN

MSL for lashing turnbuckle of thread diameter 28.6 mm
= 2.86 x 2.86 x 10 = 8,179.6 daN

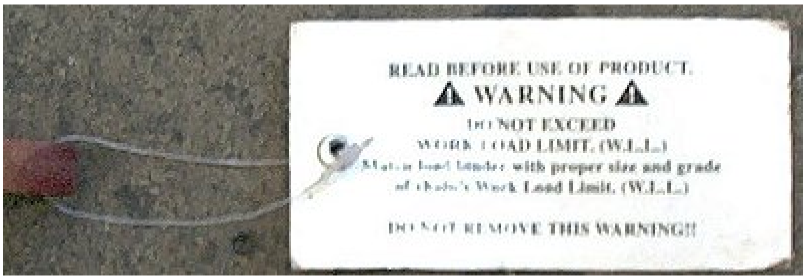
When purchasing turnbuckles, it is important that only turnbuckles with sufficiently wide nuts and weld seams are purchased. Spot welded turnbuckles are available on the market. These should not be used.

The turnbuckle shown above is generally available in three sizes: 1 1/8 " , 1¼" and 1½" thread diameter. 1 inch is equivalent to 25.4 mm.



Turnbuckle made of higher strength steel for round steel chains with short links

The manufacturer's specifications must be observed for turnbuckles made of higher strength steel. 50% of the specified breaking load is assumed as the MSL. Unless, as with this turnbuckle, a WLL (Working Load Limit) has already been specified. This then corresponds to the MSL.



Tag on a lashing turnbuckle

4.4.1.2 Lashing materials, Part 2

Lashing point on a 40' flat

The same rules of thumb apply for lashing points made of normal strength steel as for lashing shackles and lashing turnbuckles. The diameter of the ring material or the bars is critical.

	Breaking load	MSL factor	MSL	
d x d x 20		x 0.50 =	kN	(diameter in cm)
d x d x 20		x 0.50 =	daN	(diameter in mm)

Determining the diameter of a lashing point: 20 mm

MSL lashing point material diameter 2.0 cm = 2.0 x 2.0 x 10 = 40.0 kN

MSL lashing point material diameter 20 mm = 20 x 20 x 10 = 4,000 daN

Notice indicating the strength of a lashing point

Even if it is not entirely clear what is meant by a strength specification, the MSL should still be calculated using the rule of thumb.

Load on lashing points

Loads may only be applied to lashing points in a permissible manner. If a number of lashings are attached to a single lashing point, the total load must be taken into account. If lashings attached to the same lashing point are alternately subjected to load and relieved of load, every lashing can have the full MSL. If the lashings subject the lashing point to load simultaneously, the MSLs of the lashings must be distributed accordingly.

Steel strapping, untreated

Steel strapping, blued

Steel strapping can be applied quickly and easily and is therefore suitable for securing purposes on many loads.

The following values can be used for calculations for untreated steel strapping:

Breaking load		**MSL factor**	**MSL**	
Strap width w x strap thickness t	w x t x 70	x 0.70 =	kN	(measurements in cm)
Strap width w x strap thickness t	t x w x 70	x 0.70 =	daN	(measurements in mm)

Blued straps have a higher strength. It can be calculated using these values:

Breaking load		**MSL factor**	**MSL**	
Strap width w x strap thickness t	w x t x 85	x 0.70 =	kN	(measurements in cm)
Strap width w x strap thickness t	t x w x 85	x 0.70 =	daN	(measurements in mm)

A blued steel strap 32 mm wide and 1.6 mm thick would produce the following value for the MSL:

MSL for blued steel strap 36 mm wide, 1.6 mm thick = 3.2 x 0.16 x 85 x 0.7 = 30.464 kN

MSL for blued steel strap 36 mm wide, 1.6 mm thick = 32 x 1.6 x 85 x 0.7 = 3,046.4 kN

The dimensions of steel straps are often coded without specifying the dimension units. It is usual practice to encode the width in mm and the thickness in 0.1 mm. The strap referred to above would have the designation 32/16 steel strap.

Lashing point for steel strap as it is rounded

Strength values calculated by rule of thumb must not be used if the steel strap is used incorrectly.

Another important requirement is that the strapping seals are applied correctly.

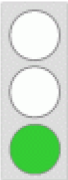
Steel straps have a very high breaking strength and this is a common selling point. The disadvantage of steel straps, however, is their low elasticity. This ranges from around 0.25% to a maximum of 0.5%. Steel straps are therefore not really suitable for use as tie-down lashings.

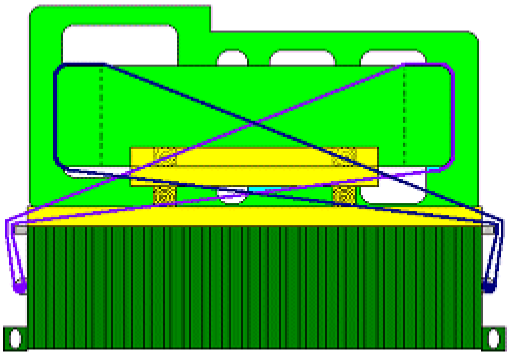
Steel straps are utterly unsuitable as tie-down lashings.

For instance, if a lashing is 7 m long, an ordinary commercial steel strap would have an elasticity of 7 m x 0.0025 = 0.0175 m or 17.5 mm. About half of this is exhausted for pretensioning, which means that just 8-9 mm remains. If the circumference of the lashing is reduced by this amount due to the strap cutting into the wood of cases, shifting of goods etc., the steel strapping will become loose and no longer able to fulfill its function as a securing aid. Further jolts during transportation then produce greater forces on account of the resulting acceleration forces which can cause the steel strapping to tear.

Compensating for the low elasticity of steel straps

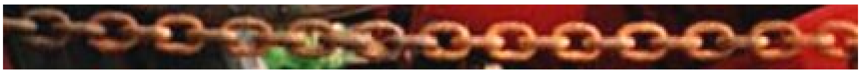
The low elasticity of steel straps can be compensated for by padding with materials with a high degree of elasticity and recovery. It is generally more convenient to use steel straps for direct lashings. They are extremely suitable for this:





Loads ideally suited for securing with steel straps

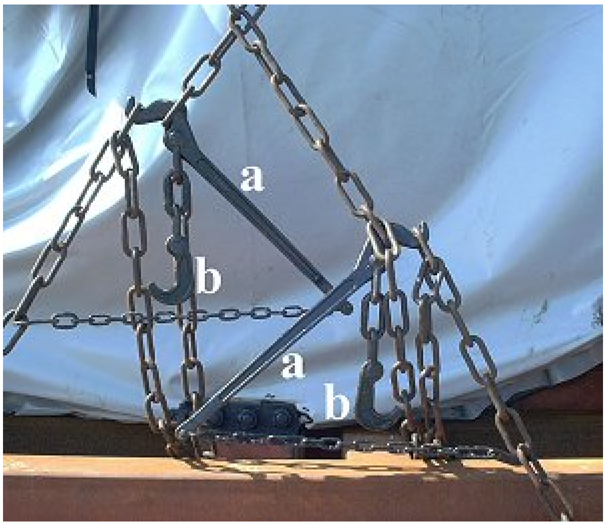
Lashing chain with long links



Lashing chain with short links

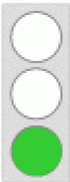
Lashing chains are generally only used to secure container cargoes if the chains will be returned. On very valuable cargoes, however, it may also be worthwhile to use them as a "lost load securing aid", because of the benefits offered by their high strength and speed with which they can be deployed.

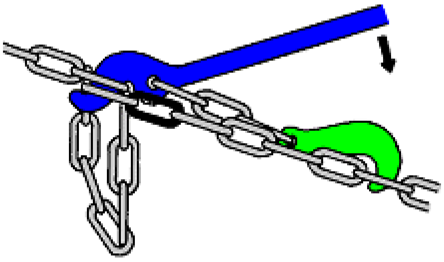
Since lashing chains are made of high strength steel, there are no rules of thumb for calculating the breaking loads. The manufacturer's specifications should be observed. The MSL may be assumed to be 50% of the breaking load. A range of different tensioning mechanisms are used with chains. Errors are frequently made when using these aids.



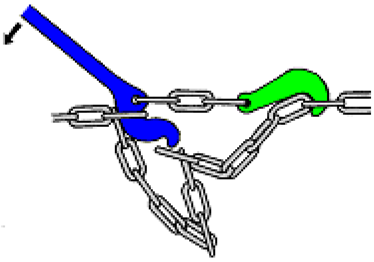
Error made using a lashing chain with tensioning lever (a) and hook (b)

Tightening the chain using the hooks:



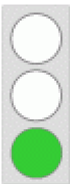


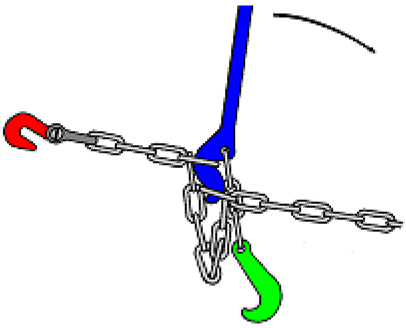
Inserting the hook



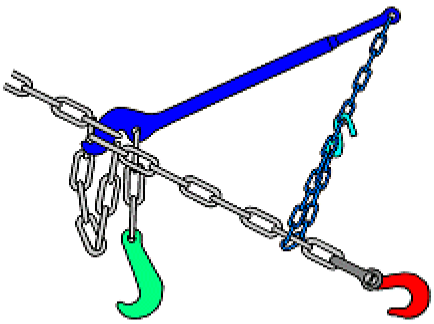
Shortening the chain

Tightening the chain with the tension lever:

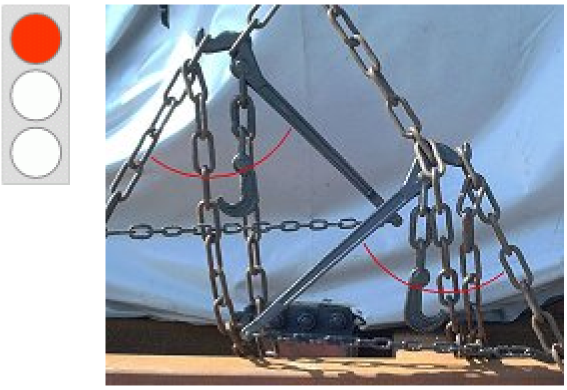


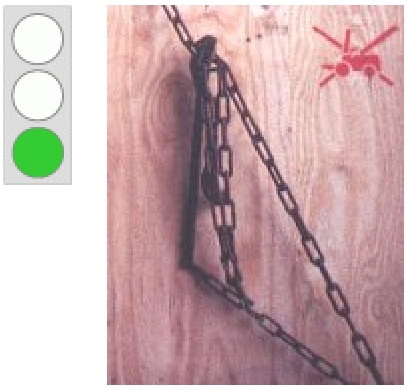


Inserting the tensioning lever



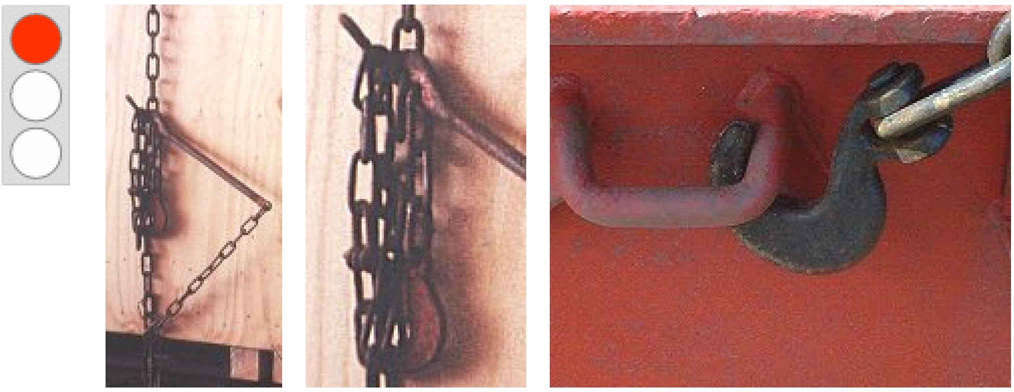
Tightening and securing the lever



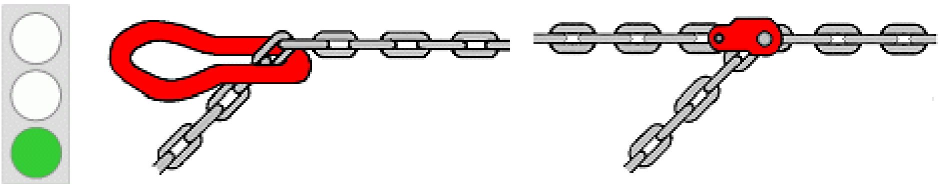


Incorrect **Correct**

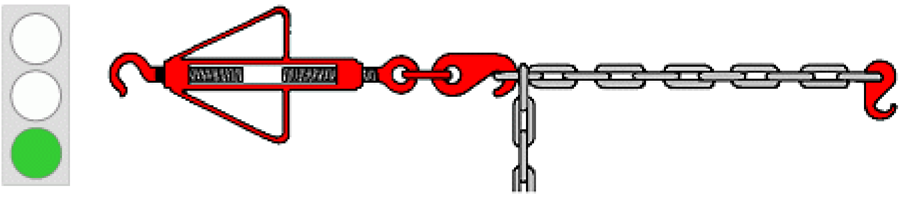
The tension levers must not remain at an angle of 90°. They must be adjusted to an angle of at least 45°. Otherwise, the tongues could buckle or shear off.



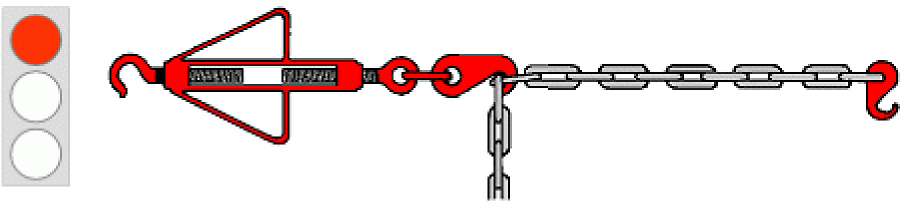
Lashed with hook **Hook incorrectly inserted**



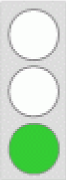
Permissible shortening of chains

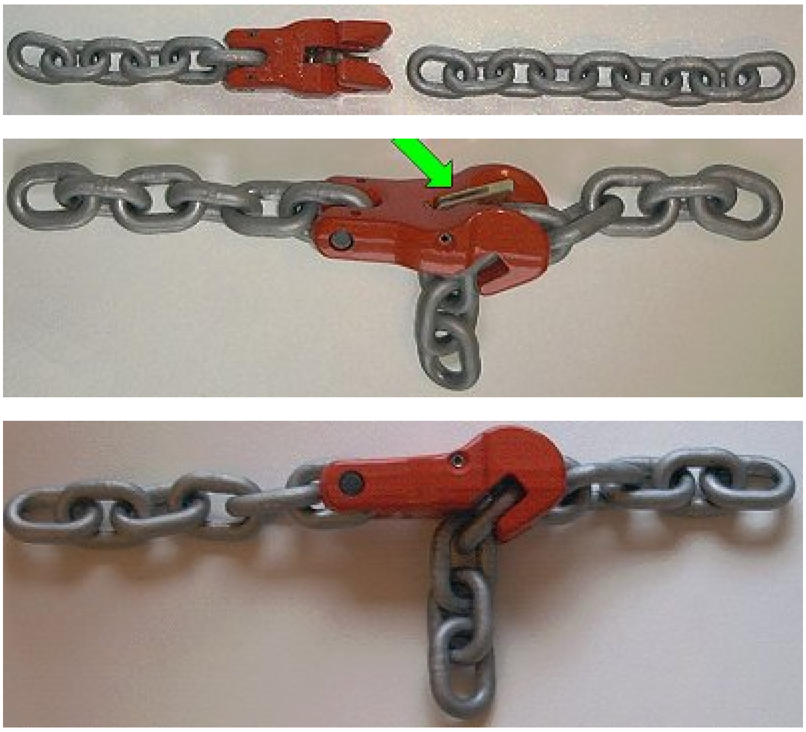


Correct shortening of a chain - no chain link is trapped



Incorrect shortening of a chain - a chain link is trapped





Shortening a chain with special claw hooks and securing lever

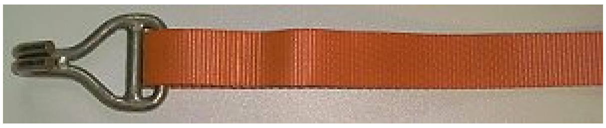
Chain tensioner (load binder)

Shortening hook on tensioner

No rules of thumb are provided in the CSS code for high strength chains, because the diversity of the products is very high. There are chains made to all kinds of different standards on the market. If the stamp on the chain and its accessories clearly identify it as quality class 8, the rule of thumb $d^2 \times 120$ can be used to calculate the breaking load. The MSL is to be assumed to be 50% of the breaking load. This produces the following figures for the following diameters of chain steel:

Diameter of steel	Breaking load	MSL factor	MSL
0.6 cm 6 mm	43.2 kN 4,320 daN	0.5 0.5	21.6 kN 2,160 daN
0.8cm 8 mm	76.8 kN 7,680 daN	0.5 0.5	38.4 kN 3,840 daN
1 cm 10 mm	120 kN 12,000 daN	0.5 0.5	60 kN 6,000 daN
1.3 cm 13 mm	202.8 kN 20,280 daN	0.5 0.5	101.4 kN 10,140 daN

4.4.1.3 Lashing materials, Part 3



Textile lashing belts

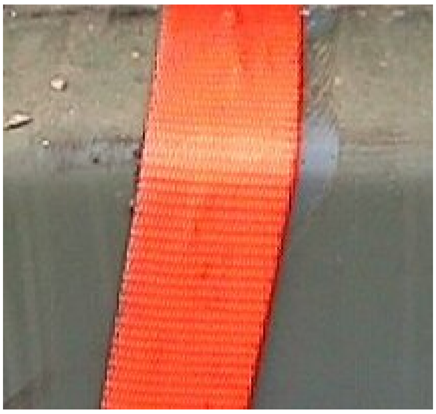
Pre-fabricated lashing belts have already been described in detail in the GDV Cargo Securing Manual. It is assumed that staff will be familiar with how to use systems of this kind and that no more than an occasional note is needed. There is no need to calculate with rules of thumb, since pre-fabricated lashing belts usually carry a label indicating the Lashing Capacity (LC). This is the permissible lashing force (F_{max}) which can be used to secure cargoes.

Polyester lashing belt

The values given on the label can therefore be accepted as the MSL. The breaking load of a belt of this kind is double this value and the standard therefore sets the LC at 50% of the breaking strength (The CSS also names "50% of breaking strength" as the permitted value).

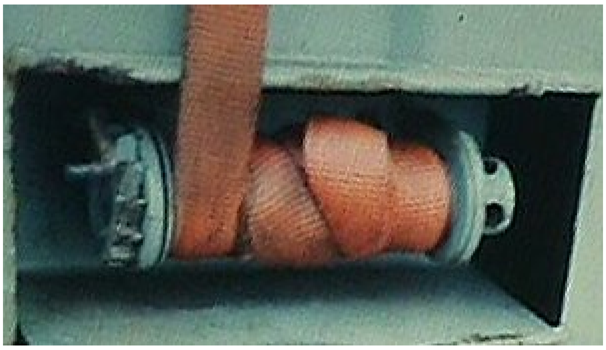
In relation to all lashings used, the proportion of pre-fabricated lashing belts is small, since the belt systems can only be returned with specific shipping companies and cargo types. Flexibility suffers in day-to-day lashing operations as a result of fixed lengths and sewn-in end fittings. Due to the speed with which they can be applied, however, the proportion of these lashings being used is constantly growing. If lashing of this kind is used, however, it should be applied out correctly and professionally.

Use of unsuitable end fittings


Chafing points due to incorrect usage of the belt

Belt systems permanently installed in containers must also be included among the pre-fabricated systems.

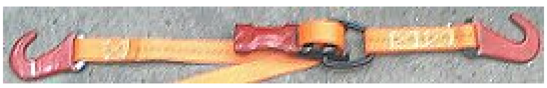



Lashing winch with incorrectly wound belt

The lashings below used to secure automobiles must also be classed as pre-fabricated goods.





Various automobile lashings

The CSS do not provide any rules of thumb for the breaking load of single-use webbing belts, but refer to the manufacturer's specifications. 70% is given as a factor for the MSL.

MSL for synthetic fiber lashing belts = breaking load as per manufacturer's specification x 0.7

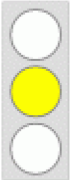
Marking on a single-use textile belt

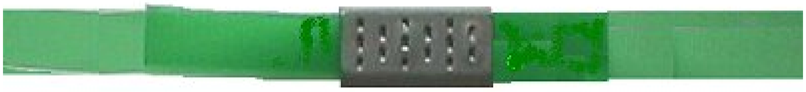
The breaking strength is specified as 3,500 kg on the label, i.e. 3,433.5 daN. The MSL would then be 70% of this, or 2,403 daN.

In the opinion of the author, this is far too high. It is well-known that in defining this factor the national interests of some IMO members played a greater role than the known problems associated with single-use lashing belts, where the quality of production differs. They are often very elastic. Some materials exhibit permanent deformation at threshold loads above 50% of the breaking load. This means that the lashings made from them will then become slack. Since they are also identical in many other ways to synthetic fiber ropes, the author recommends that at least the 50% factor of the European and German standards is assumed for pre-fabricated lashing belts. For the material discussed above, this would be a value of 1,717 daN. If the author were personally responsible for lashing work, he would only assume the value for synthetic fiber ropes, i.e. 33% of the breaking load. For a belt with a breaking load of 3,433 daN (3,600 kg), this would be 1,133 daN. Since belts are nearly always used doubled, the value would double accordingly.

Various locking devices for use with single-use textile lashing belts

It is useful and practical to have operating instructions stamped onto the locking devices.



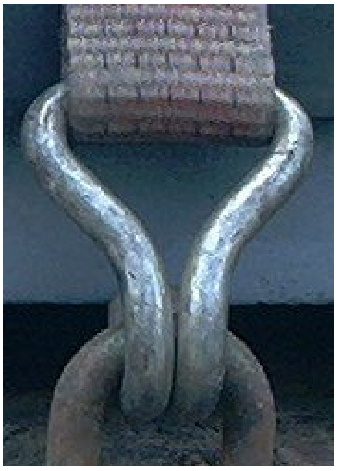


Packaging straps

Packaging straps of this kind are only suitable for securing individual, relatively light packages on pallets and similar supports as well as for unitization.

Two different types of end fittings

There are a huge variety of end fittings and other connecting elements available. It is important to select the one which best suits the lashing points on the particular cargo transport unit.

Incorrectly inserted hook

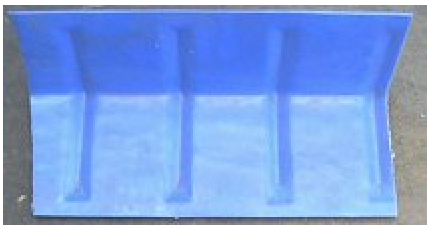
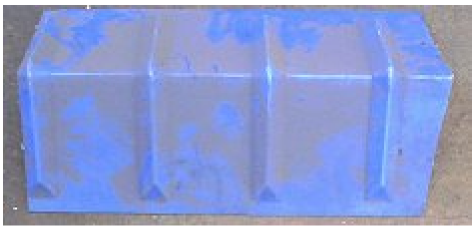
Hooks must where possible be hooked in from the bottom to the top or from the inside to the outside, so that they cannot loosen if jolted during transport, should the lashing become slack.

Belt protectors

It is essential that belts are protected against sharp edges whether this be by means of belt protectors or special sleeves. If this is not possible or items like this are not available, edge protectors are to be used:

Various edge protectors

There are a number of different devices available for tensioning textile lashing belts.

Belt tensioner

Knotted textile belts

Belts and straps must not be knotted and twisted. They must rest on a wide surface and must not be tightened over sharp edges. Damaged belt material must be removed from stock.

Knotted textile belts -
locking devices or buckles too weak

Single-use textile belts are unsuitable for use as tie-down lashing

Tight-fit friction securing with a WisaFix lashing cover

Using tarpaulins of this kind results in a combination of tight-fit and friction securing.

4.4.2 Wood

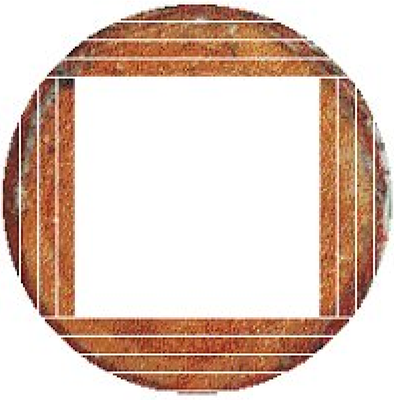
A great deal of information is provided on the use of wood and its application in load securing in the relevant sections of the examples. This section, therefore, will only provide information on basic properties of wood, the various formats, technical terms, designations and methods of cutting. Rules of thumb for calculating the strength of are also provided.

Logs

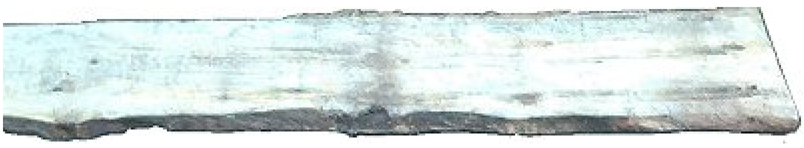
Long edge/with the grain

End grain/ across the grain

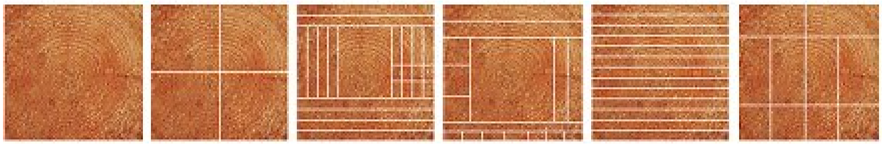
Wood is indispensable as a load securing material. A distinction is always made between the long and the short side of the wood (across the grain and with the grain). Wood is less able to withstand loads on its long edge, i.e. when the load is perpendicular to the grain. The extraction resistance of nails and screws, however, is higher when they are nailed or screwed perpendicular to the grain. In contrast, wood is far better able to withstand loads applied on the end grain, i.e. parallel to the direction of the grain.



Untrimmed edge boards or waney edge lumber are often cut from the outer sections of a log for use as wooden dunnage.



Wooden dunnage board

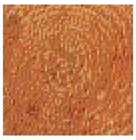


Depending on the thickness of the trunk, balks, squared lumber, battens, laths, planks and boards are cut from the trunks.

Balks

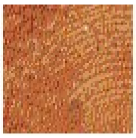
cross-stacking of balks (with errors, in this case: no overhang, dogs attached incorrectly)

Balks have very large cross-sections, with edges usually over 15 cm long, squared lumber starts as of about 8 cm x 8 cm.

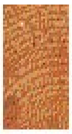


Solid wood

Halved lumber



Quartered balk



1:2 format

On solid wood, the heart, medulla or pith is located in the center, on halved lumber on the side and on quartered lumber on one corner. 1:2 can be a size such as 16 cm x 8 cm. Dimension stock could, for instance be 6.3 cm x 7.5 cm (2 1/2" x 3"). Thicker battens might be 3.2 cm x 5 cm (1 1/4" x 2") or 3.8 cm x 6.3 cm (1 1/2 x 2 1/2").

Sticked squared lumber packages

Mold on lumber which has not been sticked

Thin laths are used as an intermediate layer between lumber so ensure that it does not develop mold or rot.

Very knotty waney edge lumber

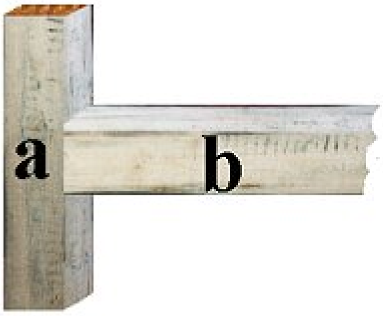
Wood with a very high frequency of knots should not be used for bracing. It must be rejected beforehand.

Squared lumber, battens and wedges - Wood which has been stained indicates that it has been treated to protect it against the sirex wasp .

The following rules of thumb can be applied to sound lumber to calculate the maximum securing load:

Softwood used for bracing, compression strength perpendicular to the grain, MSL = 0.3 kN per cm²

Softwood used for bracing, compression strength perpendicular to the grain, MSL = 30 kN per cm²



Applying the rule of thumb to compressive strength parallel to the grain of the wood

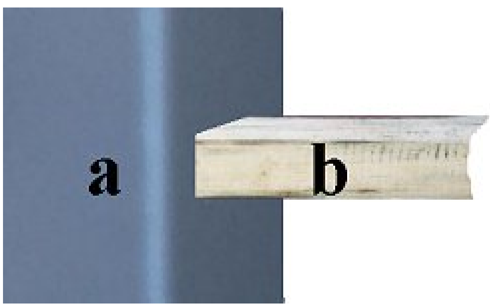
Assuming that the contact surface between a and b is 10 cm x 10 cm = 100 cm², a securing force of 3,000 daN (30 kN) can be introduced via a and transmitted to b.

The following rule of thumb applies for the maximum securing load parallel to the grain:

Softwood used for bracing, compression strength parallel to the grain, MSL = 1 kN per cm²

Softwood used for bracing, compression strength parallel to the grain, MSL = 100 daN per cm²

Note: For road and rail transportation only, 200 daN/cm² can be assumed for the load parallel to the grain, since it is assumed that only isolated or few load events occur during each transport operation. For maritime transport, the IMO halve these values to 100 daN/cm² due to the constantly changing stresses in rough seas.



Applying the rule of thumb to compressive strength parallel to the grain

Assuming that the contact surface between the steel component a and the wood b is 10 cm x 10 cm = 100 cm², a securing force of 10,000 daN (100 kN) can be transmitted between a and b.

High outlay - low strength

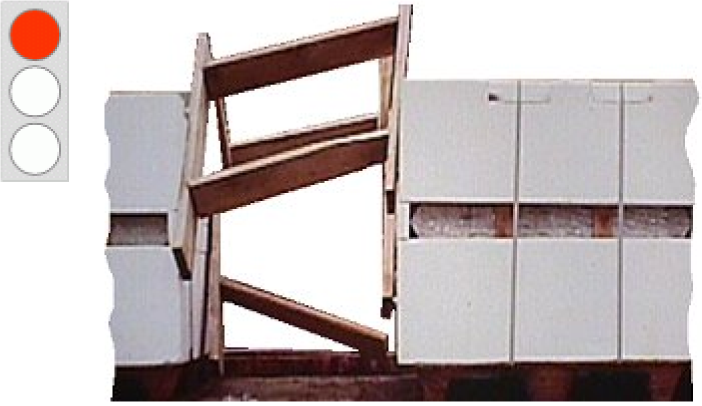
Little material - high strength

Since the grain side is crucial for the bracing shown in the left-hand illustration, four horizontal bracing elements measuring 10 cm x 10 cm will achieve an MSL of 12,000 daN. The values for the load on the end grain can be used for the bracing shown in the right-hand illustration. An MSL of 40,000 daN is achieved with significantly less outlay in terms of work and materials.

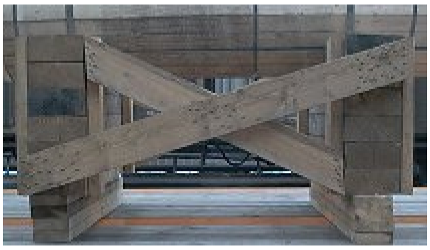
Even less material - high strength with four horizontal bracing elements used in pairs

It may be that one pair of bracing elements may be sufficient.

The traffic light really ought to be "double-green" for the figure at the top, since 40,000 daN is achieved with even less material. Probably, even the variant with only two bracing elements would suffice as shown in the bottom figure (the second bracing element is hidden by the first). Even this achieves 20,000 daN. The wood should be placed at the top for goods that are likely to topple. It can be placed at the bottom for flat goods which are not likely to topple. The bracing elements must be cross-braced against shifting so that they do not become detached.

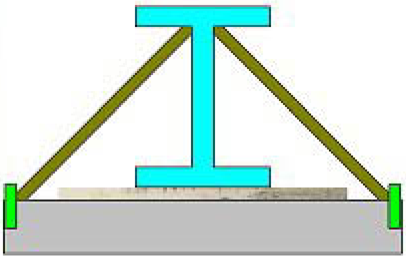


Unprofessional bracing which has become detached due to lack of cross-bracing



Heavy drive shaft on trestles

If the circular segment on which the wooden-clad drive shaft is placed is 50 cm wide and the wood on the trestle is 20 cm wide, there will be a projected area of 1,000 cm², which means a total bearing surface on the trestle of 2,000 cm². Since the compression load is perpendicular to the grain, the trestle can absorb 2,000 cm² x 30 daN/cm² at this point, i.e. 60,000 daN. Since the shaft has been placed on several trestles, they have obviously been over dimensioned here. The workmanship also leaves something to be desired. There is still some potential for rationalization here.

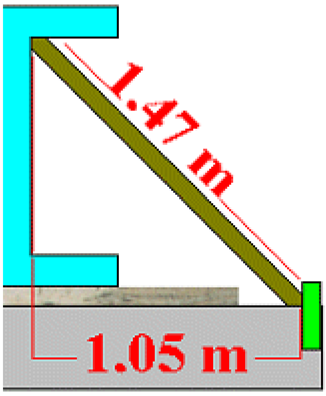


Securing with diagonal stays

Lumber measuring 10 cm x 12 cm has been used here. This would produce an area of 120 cm² at the contact points. Since two pieces of wood were used as bracing on each side, the total area is 240 cm² per side. The stays would therefore theoretically absorb 240 cm² x 100 daN/cm², i.e. thus 24,000 daN. There is however a slight problem here: The stanchions are not as wide as the lumber.

Always take note of to the smallest contact surfaces!

Since the stanchions are only 8 cm wide, only an area of 8 cm x 12 cm = 96 cm² per wooden element can be used for calculation, i.e. 192 cm² per pair of stays. In reality, therefore, the stays can only be loaded with 19,200 daN per pair.

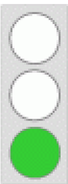
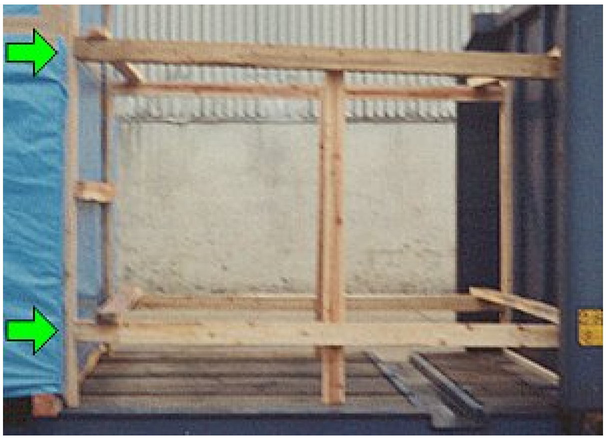


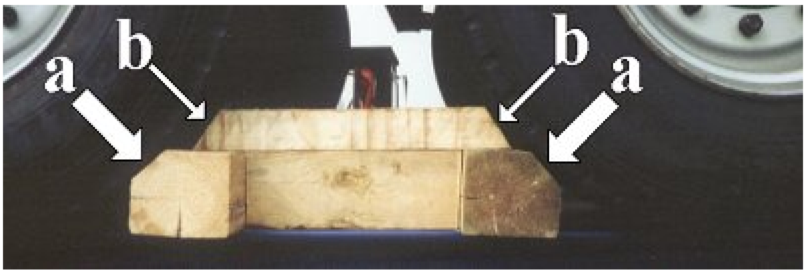
Only the lateral component is effective against tilting.

Since the total length of the stay is 1.47 m and the transverse component is calculated as 1.05 m, a pair of stays secures the beam against tilting with 1.05 m / 1,47 m x 19,200 daN = 13,714 daN.

Generally, the following rules apply:

- If it is feasible, always brace horizontally;
- If it is feasible, brace so that the end grain loading capacity is used;
- Always brace against the parts with the greatest load-bearing capacity, e.g. on cases, use the plate effect provided by the base and lid or guide the forces into the vertical sides.



Transferring forces onto the ends of the side walls of the box



Chamfered wood (a) - wood cut to a bevel (b)

Securing measures of this kind can only be created using wooden aids and driving wedges, which are removed again after securing has been completed.

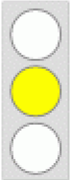

Driving wedges - tapered blocks - slim wedges

Driving wedges can be used individually or in pairs. They should be made of hardwood. The very shallow angle here produces large leverage effects which can be used to achieve extremely high forces. Caution is therefore demanded. Only drive wedges in gently and then fix them into place.

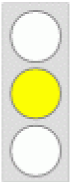
Simple stays for filling gaps which can be prepared outside the container

Sometimes only very simple structures are required to fill in a gap in the container. But one last note: The less material has to be used for load securing the better. The best and most cost-effective load securing measure is a compact stow using well-protected and sufficiently strong packages.

4.4.3 Filling material




Expanded synthetic plastics have very poor recovery properties and nearly no elasticity. They deform very quickly under load, i.e. they become thinner under compression leads. They can therefore only be used for filling gaps with relatively light loads. In all other cases, they should not be used as a filling material. The same applies for cardboard and corrugated board.




Used tires may to a certain extent be suitable for filling in gaps, but not as has been done here: Ring-shaped point loads may occur. To enable them to fill in a large area, they could be arranged so that they are pressed between two walking boards which each cover a large surface area of the cargo.

Again, we quote the CTU guidelines:

> *3.2.12 When deciding on packaging and cargo-securing material, it should be borne in mind that some countries enforce a garbage- and litter-avoidance policy. This may lead to limitations on the use of certain materials and imply fees for the recovery of packaging at the reception point as well as similar problems for the shipper of the cargo. In such cases, reusable packaging and securing material should be used. Increasingly, countries are requiring timber dunnage and packaging materials to be debarked.*

Airbags

> *3.2.4 If airbags are used, the manufacturer's instructions on filling pressure should be scrupulously observed. Allowance should be made for the possibility of a considerable rise in the internal temperature of the CTU above the temperature at the time of packing. This may cause the bags to expand and burst, thereby making them ineffectual as a means of securing the cargo. Airbags should not be used as a means of filling space at the doorway unless precautions are taken to ensure that they cannot cause the door to open violently when the locking bars are released.*

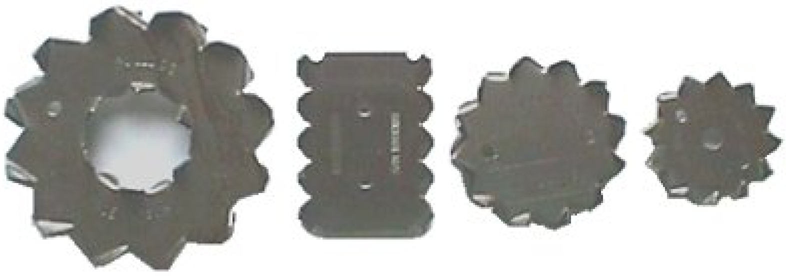
The most commonly used form of airbag comprises a multilayer paper bag available in a wide variety of different sizes. This type should only be used if the areas to the left and right of the gap are as smooth as possible and have a high load-bearing capacity. If necessary, walking boards are to be provided to ensure correct distribution of pressure. Special measures are required for working with airbags, in particular with white and brown goods, since the parts of the cartons which are not padded would be pushed in. The minimum inflation pressure should be 200 hPa. For many airbags, this is around 300 hPa. This can still achieve a securing force of 3,000 daN per m². Airbags are inflated using compressors. Special inflation fittings with pressure reducers are required.

Special fittings enable the air to be evacuated. This is an advantage if a bag is not seated correctly, as it can quickly be deflated and then inflated again. This fitting facilitates deflation of reusable bags. Since it is time-consuming to have to unscrew valves to let out the air, the recipient will generally deflate single-use bags by puncturing them. When closing gaps, airbags which have already been partially inflated should be placed in the stowage gap and then completely inflated. Suitably large and smooth surfaces are required on the cargo transport units when using them. Only airbags which are capable to a certain extent of withstanding point loadings should be used. One important factor with regard to usability is that their side faces should be as near as possible to parallel. Air bags with a pronounced bulge must not be used.

4.4.4 "Artificial tight fit"

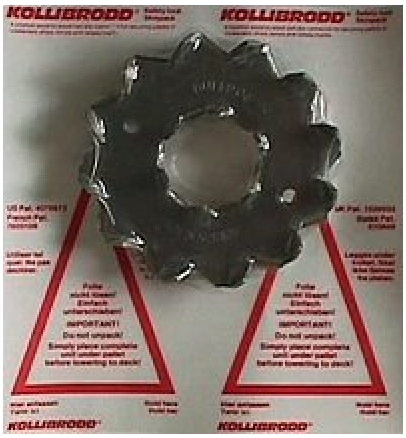
Gangnails - without and with nail holes

Gangnails of this kind, sometimes known as dowels, can be used to provide a tight fit. They are available in a wide variety of different shapes and sizes. The specialist literature also refers to these as "shear transfer plates". They are punched pieces of steel sheet with triangular teeth bent upward and downward.



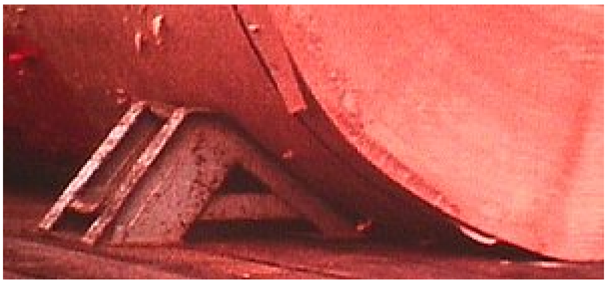
Different shapes and sizes of shear transfer plates

To facilitate handling, these devices are also available in "display packaging". Then they are shrink-wrapped ready-to-use and can be inserted simply.



Aids like this make sense when unitizing packages with robust softwood surfaces, e.g. single-use pallets, softwood pipe clamps, cases with suitable skids or belt battens etc. If gangnails are laid between loads of this kind and then the loads are strapped or bound together in some other way, they will increase cohesion. If it is possible to lay them on platform containers with softwood floors, they can contribute to improving load securing or to reducing the remaining securing work. On their own, they are not sufficient as a means of securing. Under stress, the teeth bend and flatten and consequently become virtually ineffective. This has been confirmed by testing carried out on unsecured loads.

In box containers it is conceivable to use them between individual package layers, but not practical, since accessibility is difficult in most cases. Unless special aids are used to lay them. Because of the risk they pose, they should not be used on container floors made of plywood or textured coated board.



Spike-based chock on a roll of liner boards

It makes sense to use spike-based chocks on cargo transport units with soft floors which allow this. A further requirement is that cylindrical goods can be placed against the chocks. When securing cylindrical goods with for instance four spike-based chocks, the load would have to be set down, the chocks put in place, the load raised, the chocks secured and the load then set down again. If the positions of the chocks are measured accurately and they are placed beforehand, the first steps can be omitted, but the product must be put in place from above. The applications for spike-based chocks of this kind are generally very limited. In the field of container traffic, they could only be used on platform containers.

4.4.5 Friction and friction-enhancing mats

A fundamental distinction is made between two types of friction, internal and external.

External friction is used to refer to the resistance that is created as a result of the relative movement as the contact surfaces of two objects rub against each other. External friction is caused, in particular, by forces of adhesion and unevenness on the surfaces of the objects. Friction is virtually independent of the size of the contact surfaces. Friction is often also explained as the meshing of two materials in contact with each other at a microscopic level.

The structure of softwood on the grain edge

This can be seen clearly, if for example, the structure of softwood is examined on the grain edge. It is not difficult to imaging that two surfaces of this nature will become 'meshed' if they are in contact with each other.

The frictional force F_F is always counter to the current movement of an object. The magnitude of the frictional force is dependent on the magnitude of the normal force F_N with which the contact surfaces press against each other and on the friction coefficient μ. Thus, the basic formula for Coulomb's law of friction is:

$$\boxed{F_F = \mu \cdot F_N}$$

In this formula μ stands for the friction coefficient or friction factor. It is dependent on the material, the state of the surfaces (roughness and whether it is lubricated) as well as the sliding speed of the bodies rubbing against each other. The symbol used in the formula is μ, the lowercase Greek letter "m" = "mu". Different types of friction are distinguished, depending on whether or not there is relative movement between the bodies, whether the bodies are already moving and if so whether they are sliding or rolling:

- **Static friction**
- **Sliding friction**
- **Rolling friction**

If the conditions are otherwise identical, the static friction coefficient is always larger than the sliding friction coefficient and the rolling friction coefficient is usually much lower than the sliding friction coefficient. During frictional processes, mechanical energy is converted into heat, frictional heat.

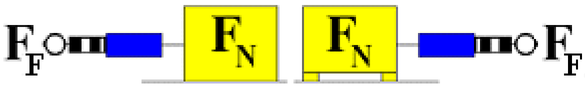
Internal friction is due to molecular forces. It occurs when individual components of a liquid or a gas, or the various layers that make up a substance, rub against each other. The technical term is viscosity. There are two types of viscosity, dynamic and kinematic.

Contact surfaces between liquids and gases, on the one hand, and the walls of a pipe both exhibit resistance which is referred to as **pipe friction**.

Friction in the service of mankind. Without friction - our lives would be impossible. All forms of locomotion are ultimately reliant on friction. When transferring forces, for example, when starting or braking a vehicle or securing a load, high levels of frictional resistance are desired. All movement in gearboxes, when moving loads etc. the objective is to keep frictional resistance as low possible in order to reduce the loss of energy to a minimum.

Friction testing. In order to determine the level of frictional resistance, very simple tests can be used. The resistance to movement can be determined using measurements of force or comparisons of mass, or, measurements can be carried out to show the gradient at which an object on a slope remains in position, starts to move or remains in motion.

Test configuration used to determine frictional resistance by measuring forces:



Static friction is measured when a measuring instrument, for example, a spring balance, is pulled until the frictional force F_F is almost sufficient to move the object being pressed onto the surface by the normal force F_N. The force that is required to keep the object in motion and pull it across the surface corresponds to the sliding friction. When applied to a vehicle, this principle can be used to determine the rolling friction. A more detailed test can distinguish between static rolling friction and sliding rolling friction. In the field of load securing, the values for sliding friction are of most interest.

The simple method described here is not admissible for determining friction in genuine scientific studies. There are special standards which detail how friction coefficients should be determined.

Example: A block of wood with a normal force or weight-F_N of 90 N is dragged over a cardboard floor. The friction coefficient F_F is measured at 27 N. After transformation of the basic formula $F_F = \mu \times F_N$ this results in:

$$\boxed{\mu = \frac{F_F}{F_N} = \frac{27\,\cancel{N}}{90\,\cancel{N}} = \underline{\underline{0.3}}}$$

For this example, the friction coefficient of wood on cardboard is calculated as 0.3. This value can also be expressed as 30% or three tenths. If the test block is doubled by the addition of an additional block, and increased to 180 N, then the frictional force is increased to 54 N. The frictional coefficient of 0.3 does not actually change, because 180 N divided by 54 N = 0.3. The friction coefficient remains constant for any given pair of materials.

If the normal force of an object and the friction coefficient are known, then the frictional force can be calculated mathematically. Thus, the calculation for the above example is as follows:

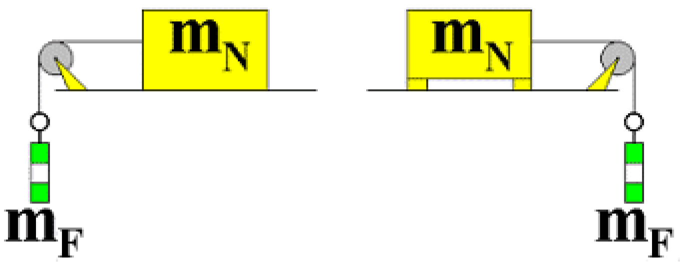
$$\boxed{F_F = \mu \cdot F_N = 0.3 \cdot 90\,N = \underline{\underline{27\,N}}}$$

$$\boxed{F_F = \mu \cdot F_N = 0.3 \cdot 180\,N = \underline{\underline{54\,N}}}$$

If the friction coefficient remains the same, the frictional force is always proportional to the normal force or weight. Thus if the normal force is doubled, the frictional force is doubled. Likewise, if the normal force is halved then the frictional force is also halved. If the friction coefficient and the frictional force are known, the basic formula $F_F = \mu \times F_N$ can be transformed and used to calculate the normal force or weight:

$$\boxed{F_N = \frac{F_F}{\mu} = \frac{27\,N}{0.3} = \underline{\underline{90\,N}}} \quad \boxed{F_N = \frac{F_F}{\mu} = \frac{54\,N}{0.3} = \underline{\underline{180\,N}}}$$

A test configuration used to calculate the frictional resistance by comparing mass may be as follows:



Sufficient weight m_F is added until the mass m_N only just remains motionless. When the masses start to move, weights can be removed. The formula that is used to calculate the friction coefficient and the transformed formulas based on it are:

$$\boxed{\mu=\frac{m_F}{m_N}} \quad \boxed{m_F=\mu\cdot m_N} \quad \boxed{m_N=\frac{m_F}{\mu}}$$

Strictly speaking, friction is still being determined using forces, since all masses are forced onto surfaces by the gravitational pull of the earth.

Example: A block of concrete with a mass m_N of 200 kg is pulled over a wooden surface. The mass m_F required to overcome the friction is determined to be 80 kg. In accordance with the formula $\mu = m_F / m_N$ this gives a friction coefficient of μ = 80 kg / 200 kg = 0.4.

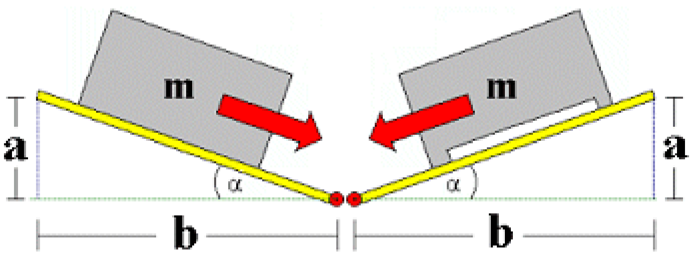
If the friction coefficient and the mass of an object are known, then the required frictional force can be calculated mathematically. Thus, for the example:

$m_F = \mu \times m_N$ = 0.4 x 200 kg = <u>80 kg</u>

If the friction resistance and the friction coefficient are known, then the mass can be calculated:

$m_N = m_F / \mu$ = 80 kg / 0.4 = <u>200 kg</u>

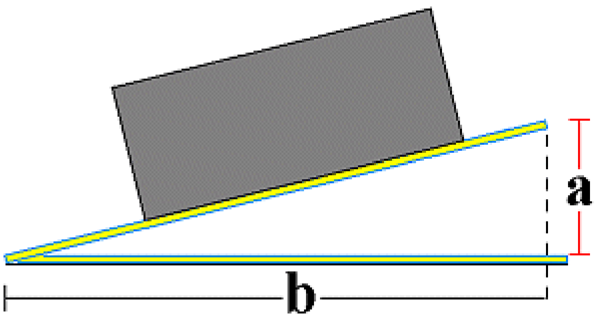
Possible test configuration used to determine the friction resistance on an inclined surface:



If no dynamometers or calibrated weights are available to determine the friction coefficient, the values can also be determined using an inclined surface. The surface is raised until the mass just starts to slide or roll. Once it has started to move, a lower angle of slope is sufficient to keep the object in motion.

There are two methods of determining the friction coefficient μ using a gradient or a sloped surface. One option is to divide the height of the sloped surface by the length of its base.

$$\boxed{\mu=\frac{a}{b}}$$

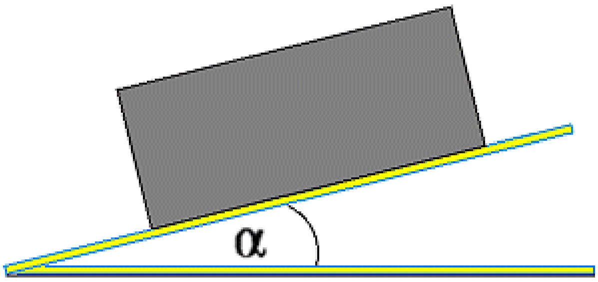


Example: An aluminum block is placed on a rusty steel plate which is raised at one edge. The height at a is measured at 96 cm. The length b is measured at 3.84 m. Using the formula $\mu = a / b$, this gives a friction coefficient of μ = 0.96 m / 3.84 m = 0.25.

The friction coefficients determined using the sloped surface always correspond to the gradient of the slope expressed as a percentage. A μ value of 0.25 determined by a test such as this means that the slope has a gradient of 25%. Thus, if the friction coefficient of car tires on an icy surface is calculated at 0.1 this means that the car is able to drive on a maximum gradient of 10% on black ice.

If a pocket calculator with trigonometrical functions is available, or a table showing the values of the trigonometrical functions, then μ can be calculated using the angle of the incline. In this case the formula is:

$$\boxed{\mu = \tan\alpha}$$

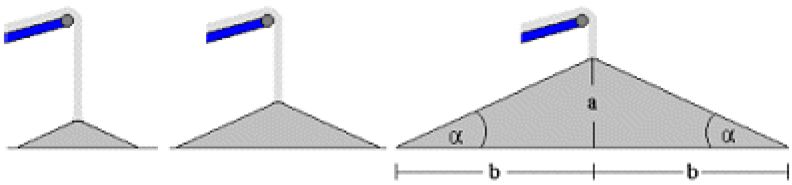


Example: Going back to the aluminum block on the rusty steel surface, the angle necessary for the block to begin to slide is 14°. The tangent of this angle is 0.25 and corresponds to the friction coefficient μ.

By transforming the formula, two known values can always be used to calculate a third unknown value:

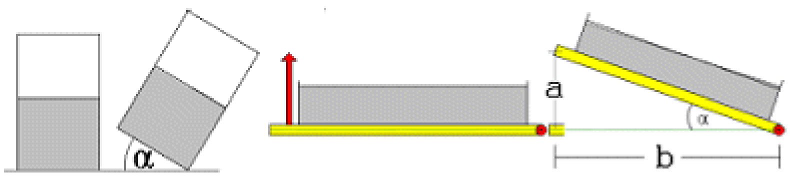
$$\boxed{\tan\alpha = \frac{a}{b}} \quad \boxed{a = b \cdot \tan\alpha} \quad \boxed{b = \frac{a}{\tan\alpha}}$$

Calculating the friction coefficient μ for bulk cargo. When using a conveyor or grab to move bulk cargo, when shoveling, tipping or pouring bulk cargo, the natural slope angle or angle of repose is formed naturally.



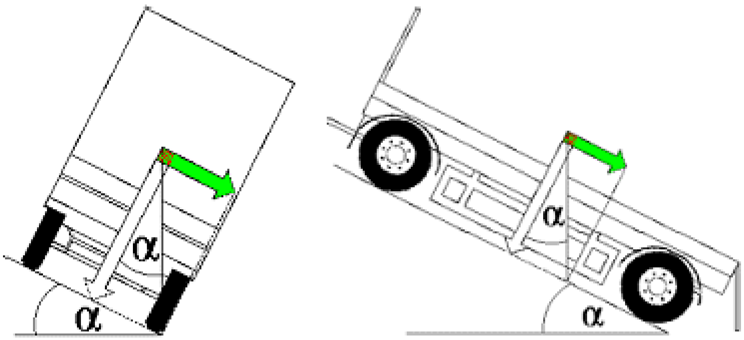
Formation of a cargo mound with a slope angle or angle of repose of α

Using the formulas for inclined surfaces, the friction coefficients (μ values) can be calculated. The value of the friction coefficient results when the height of the heap (a) is divided by the base length of one of the flanks (b) or the tangent of the angle of repose or slope angle (α) between the slope of the heap and the horizontal plane is calculated. During testing, values are determined by leveling the surface of the contents of a receptacle and then either tipping the receptacle or placing it on a surface which is then raised at one edge until the contents start to slide/flow.

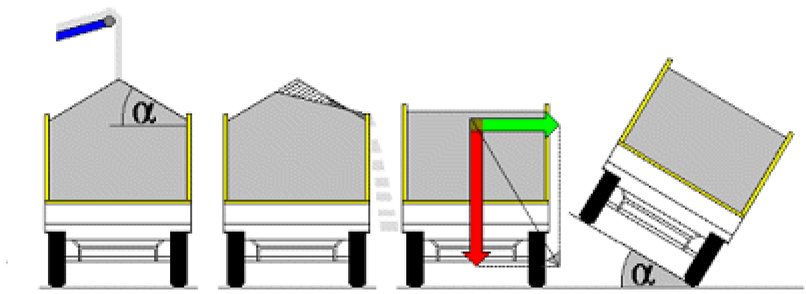


Examples: A glass of salt with a level surface is tipped until the first grains of salt break from the surface. A tipping angle α of 31° is determined. The tangent of 31° can be used to determine the friction coefficient of this type of salt as μ = 0.6. A receptacle containing leveled peas is standing on a surface which is subsequently raised until the individual peas start to roll/slide. The height a = 1.36 m and the base length of the inclined surface b = 4.00 m are used to calculate a friction coefficient for peas of μ = 0.34. Checking using the measured tipping angle of 18.8° confirms the friction coefficient: tan 18.8° = 0.34.

To completely empty bulk containers on vehicles at tipping points, the loading platforms must be raised so that the "tipping angle" ɑ is reached or exceeded:



With respect to the safe transportation of bulk cargoes, particular attention should be paid to the fact that loads are leveled off before the vehicle is driven off:



If this rule is not followed, the load may begin to slide and overflow at very low acceleration. The picture on the far left shows a bulk load heap left in its natural state. The next picture shows that lateral acceleration of just 0.2 g would cause the shaded portion of load to slide from the vehicle. The next picture shows a vehicle where the heap has just been leveled. With the cargo loaded in this manner, it requires a lateral acceleration force of 0.6 g to make the cargo slide. The gradient which corresponds to 0.6 g is shown in the picture on the far right. The angle ɑ is identical to the slope angle ɑ of 31°.

The **angle of repose, slope angle or discharge angle** as well as the **friction coefficients of bulk cargo** are all affected to a great degree by the moisture content of the cargo, the size of the grains and other similar factors.

Test observations. Running tests and noting the measured data for different materials and masses or objects with varying weights will allow the following conclusions:

Bearing area. Insofar as the objects do not press into the surface, the dimensions of the bearing area have no influence on the magnitude of the friction resistance.

Weight/mass. Under otherwise identical circumstances, the friction resistance of objects is proportional to their mass/weight. Thus, doubling the mass will double the friction resistance, and halving the mass will halve the friction resistance, etc.

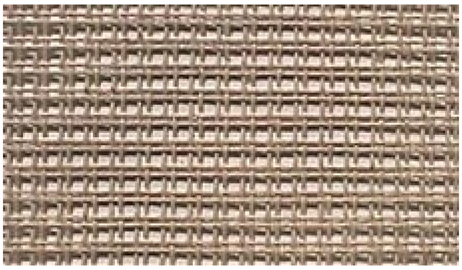
Material. The materials which are in contact are what determine the values observed. The magnitude of the friction coefficient depends solely on which materials are making contact.

Units of measurement when using the basic formulas. For all calculations using the basic formulas $\mu = F_F / F_N$, $\mu = m_F / m_N$ and $\mu = a / b$ it is not relevant which unit of measurement is used to measure force, mass or distance. The important thing is that they are used consistently. Since the calculation dimensions in the formula cancel each other out, μ is a dimensionless numerical value.

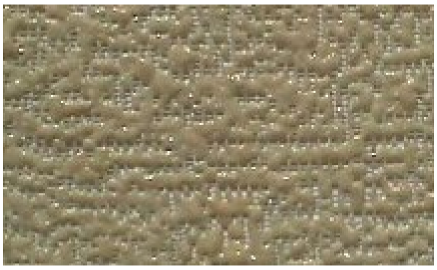
Units of measurement when using the transformed formulas. With these calculations, care must be taken to ensure that the same mathematical dimensions are used, otherwise the results will not be suitable for comparison or will need to be converted. Writing down the mathematical dimensions guarantees the correct results, because errors can be spotted immediately.

Sliding friction coefficients. For load securing, the sliding friction coefficients are of particular importance. The following table contains sliding friction coefficients for selected general and bulk cargoes as well as a number of materials that are used on a regular basis. The values are taken from our own tests. The abbreviation FE mat stands for friction-enhancing mat.

Table 1a - Sliding friction coefficients for selected materials				
Material pairs	Friction coefficient μ as			Discharge angle
Surfaces in contact or bulk cargo	Decimal	Fraction	Gradient	
Stones/loose soil, certain varieties of ore and coal	1	1/1	100%	45°
Friction-enhancing mats or car tires/very rough concrete, FE mat on FE mat (gum)	0.9	9/10	90%	42°
FE mat/rough concrete, rough wood or rough chipboard; tire rubber/macadam; certain types of paper/FE mats	0.8	4/5	80%	38.7°
FE mat/rusty steel or matt varnished wood, tire rubber on rough materials	0.75	3/4	75%	36.9°



Material with a μ value of approximately 0.8

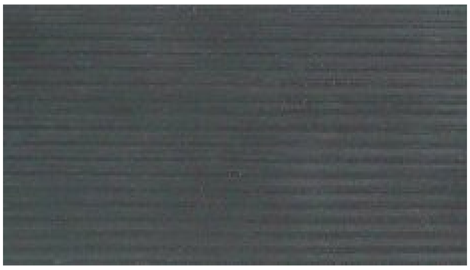


Material with a μ value of approximately 0.7

Materials of this type are ideal for use as interlayer dunnage when layering goods that are unitized with suitable strapping.

They are less suitable for use as underlay or interlayer dunnage for unsecured loads or partial loads. As vibrations occur, the friction coefficient drops dramatically and the items will start to move. These relatively thin materials tend to wear easily. At times, particularly if they are heated, these materials can even have an adhesive effect which can depreciate the value of sensitive goods.

Table 1b - Sliding friction coefficients for selected materials				
Material pairs	Friction coefficient μ as			Discharge angle
Surfaces in contact or bulk cargo	Decimal	Fraction	Gradient	
Rough galvanized sheets, rough ekki (Azobé) or softwood/FE mat; very rough concrete or stone/very rough concrete, FE mat (gum)/wood or PE	0.7	7/10	70%	35°
FE mats or rough stones or concrete/rough wood, planed oak or smooth plywood/FE mat; very rusty steel/very rough wood; car tires/wet road; various cereals as bulk cargo	0.6	3/5	60%	31°
FE mat/PA; rough concrete or rough stones/rough wood, very rough concrete/rough concrete, various materials/FE mats	0.5	1/2	50%	26.6°



Materials with a μ value of approximately 0.6

These materials can be used to maintain friction coefficients of approximately 60%. The material on the left is available in a number of different thicknesses, but usually 6 mm and 10 mm thick. The thicker version is preferable for use with heavier goods because it doesn't wear quite so quickly. Materials of this sort are usually composite materials from rubber scrap and recycled rubber etc. The material on the right is just 2 mm thick and has a ridged surface. This is more suitable for forming unit loads.

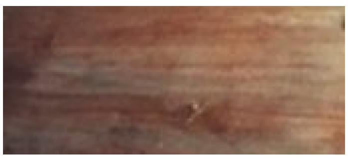
In some cases, friction-enhancing materials cannot be brought into the containers, because they would hinder the normal work. This method can only really be implemented if the goods can be placed cleanly on prepared pads or strips. This method can also be used when loading open top containers or platform containers where the intended positions are easily accessible to staff and equipment. The use of non-slip materials is impossible if the length or any other characteristic of the load requires it to be pushed into the container.

Table 1c - Sliding friction coefficients for selected materials				
Material pairs	Friction coefficient μ as			Discharge angle
Surfaces in contact or bulk cargo	Decimal	Fraction	Gradient	
Aluminum profiles/FE mats;	0.45	9/20	45%	24.2°
Rough wood/matt varnished wood; aluminum/FE mat; rusty steel/very rough softwood or oak; certain types of paper/PE; very rusty steel/very rusty steel; concrete/wood; concrete/concrete; minimum value for FE mats	0.4	2/5	40%	21.8°
Rough wood/wood; rough wood/PE; aluminum/softwood or PE; rusty steel/rough wood; rough galvanized steel plate/softwood; certain types of paper/cardboard or wood; concrete/wood; wood/wood; wood/special plastic films; car tires on snow	0.3	3/10	30%	16.7°
Matt varnished wood/PE; rough chipboard/softwood; rough chipboard/PE; planed ekki (Azobé)/softwood; plywood/softwood; paper/wood; steel/aluminum	0.25	1/4	25%	14°

Softwood

In practice, dry softwood should not be calculated with a friction coefficient greater than 30%.

Table 1d - Sliding friction coefficients for selected materials				
Material pairs	Friction coefficient μ as			Discharge angle
Surfaces in contact or bulk cargo	Decimal	Fraction	Gradient	
Planed oak, PA/softwood, PE; Bongossi, plywood/PE; FE mat/sanded wooden loading platform; rusty steel/PE, PA; rough galvanized steel/PA; contaminated steel/aluminum; dusted steel/ rough wood; wood, cardboard on textured coated board, PVC, plastic coated wooden floors etc.	0.2	1/5	20%	11.3°
PA/PE, rough galvanized steel/PE; rough wood/sanded wooden loading platform	0.15	3/20	15%	8.5°
Aluminum, PA, PE, steel, wood and various other materials on heavily sanded or contaminated FE mats; smooth steel on smooth steel; tires on ice	0.1	1/10	10%	5.7°
Water, oil and other liquids	0.0	0/∞	0%	0°



Normal container floor

With normal container floors made of plywood or textured coated board, a maximum friction coefficient of 20% can be reckoned with. Even if the floor has been steam cleaned and dried thoroughly, when packers walk/drive across the floor, dust and other contamination is usually deposited thus lowering the friction.

Factors which alter the friction coefficients. The values given are just guidelines. Strictly speaking, each shipper should themselves determine the values that should be used in their situation. But beware: The values obtained under laboratory conditions are rarely the same as those that occur in practice. External influences, such as humidity, dust and grease can affect the figures considerably. Dirty loading areas with the remains of granular materials, such as sand, etc. reduce the friction coefficient considerably. Some of these values are given in table 1. The friction coefficient can, in particular, be reduced considerably by vibration, and in a worst case scenario it may even be reduced to values approaching zero.

Ultra-smooth container floors

When using containers with very smooth floors, it is recommended not to rely on friction, but instead to pack and secure the load in such a way that it cannot move, even without friction.

VDI 2702. Guideline VDI 2702, published by the Verein Deutscher Ingenieure, and entitled "Ladungssicherung auf Straßenfahrzeugen - Zurrkräfte" (Load securing on road vehicles - Lashing forces) gives the following sliding friction coefficients:

Table 2a - Sliding friction coefficients in accordance with the VDI Guidelines			
Material	Dry	Wet	Greasy
Wood on wood	0.20 - 0.50	0.20 - 0.25	0.15 - 0.05
Metal on wood	0.20 - 0.50	0.20 - 0.25	0.10 - 0.02
Metal on metal	0.10 - 0.25	0.10 - 0.20	0.10 - 0.01

The VDI Guidelines recommend using the lowest value for the sliding friction coefficient μ if in any doubt. In addition, attention is drawn to the fact that additional material pairs and environmental influences, such as dirt and ice, require that the friction coefficients should be estimated or should be determined specifically by testing.

The following table gives sliding friction coefficients from the VDI guideline expressed as fractions, as gradients in% and as angles:

Table 2b - Sliding friction coefficients in accordance with the VDI Guidelines									
Material	Dry			Wet			Greasy		
Wood on wood	1/5 through 1/2	20% through 50%	11.3° through 26.6°	1/5 through 1/4	20% through 25%	11.3° through 14°	3/10 through 1/20	15% through 5%	8.5° through 2.86°
Metal on wood	1/5 through 1/2	20% through 50%	11.3° through 26.6°	1/5 through 1/4	20% through 25%	11.3° through 14°	1/10 through 1/50	10% through 2%	5.7° through 1.15°
Metal on metal	1/10 through 1/4	10% through 25%	5.7° through 14°	1/10 through 1/5	10% through 20%	5.7° through 11.3°	1/10 through 1/100	10% through 1%	5.7° through 0.57°

Here it should be noted that the issue of friction is under review by the Verein Deutscher Ingenieure and the figures given above are now obsolete (information as at the beginning of 2002).

Rolling friction coefficients are much lower than static or sliding friction coefficients. Values for common materials are shown in the following table:

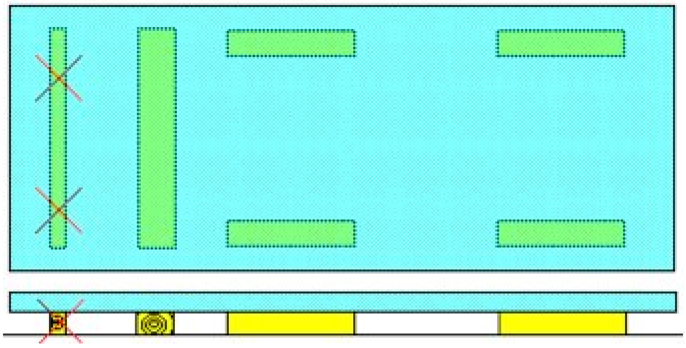
Table 3 - Rolling friction coefficients of selected materials				
Material pairs	Friction coefficient μ as			Overflow angle
Surfaces in contact or bulk cargo	Decimal	Fraction	Gradient	
Roundwood, rollers and wheels on an unmade surface	0.5	1/2	50%	26.6°
Roundwood on rough surface	0.2	1/5	20%	11.3°
Roundwood on asphalt, steel or other firm surface	0.1	1/10	10%	5.7°
Wheels with air-filled tires on a firm surface	0.02	1/50	2%	1.15°
Steel wheels traveling on rails with flanged wheel grooves, starting and pushing on free tracks	0.01	1/100	1%	0.57°
Railroad wheels on free tracks, or clean flanged wheel grooves	0.0025	1/400	0.25% 2.5‰	0.14°

Squared lumber with a square cross-section can act like rollers. This risk is particularly high when using waney edge squared lumber since this often behaves in a similar way to roundwood.

Never stand rectangular beams on edge. Rectangular formats or, better, planks should be used flat. The thickness should be calculated in order to ensure that lifting gear or ground conveyors are able to handle the goods. A better format is the so-called "sandwich" which combines wood with top-quality friction-enhancing mats glued or screwed to each side. The gluing or screwing can be made more durable if the lumber is shaped to accommodate the mats. The depth should be measured in such a way that even when a heavy load is placed on the mat, the FE material is not crushed to such an extent that the goods are resting on the wood.

Incorrect, and incorrectly used lumber dunnage

If transport jolts are to be expected transversely to the orientation in which they are laid, rectangular formats such as planks are to be used. It would be better to set out the beams parallel to the expected direction of the jolts, but for handling reasons, this is only rarely possible.



Risk of rolling with incorrect and correct use of wooden dunnage

As has already been mentioned, frictional forces can be reduced to zero as a result of vibration. A certain minimum amount of load securing should always be implemented to counteract the effects of vibrations. Goods should never be transported unsecured just because the calculated or assumed friction coefficients are greater than the horizontal acceleration that is to be expected. With very few exceptions, for example, when materials are not compatible or the selected handling methods do not permit the use of friction enhancing mats, friction should always be enhanced as much as possible by selecting the appropriate materials. Since the use of tensioning or lashing aids or vertical bracing creates additional frictional forces, the load securing outlay may be reduced considerably if high friction coefficients can be achieved.

5 Examples of packing and securing

This part of the container handbook is divided into three main sections:

5.1 This section deals with modularized cargoes, which require a minimum of securing effort, but may very well consist of a variety of types of cargo.

5.2 This section contains instructions relating to the packing of individual cargoes and homogeneous container cargoes, i.e. those which consist of the same types of shipped goods or cargo units.

5.3 This section deals with the packing and securing of heterogeneous, i.e. different or dissimilar, shipped goods or cargo units. This variant occurs most frequently with grouped loads.

Each individual shipped item, or each cargo group makes specific demands on the type of cargo transport unit used and the manner of packing or securing. Differences arise due to the characteristics of the goods carried and the shipping presentation or packaging used, which determine, or at least influence, compatibility, shape, strength, packing and securing options.

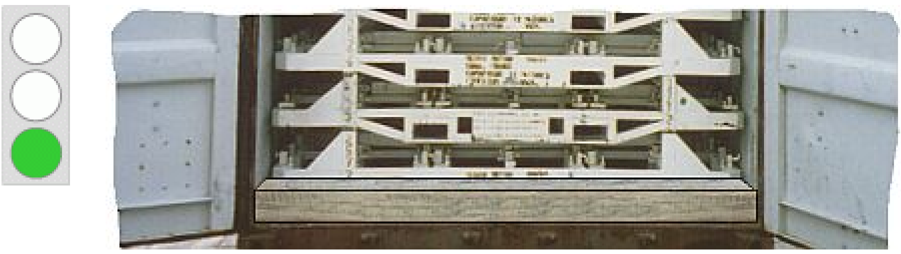
5.1 Containerized and modularized loads

Section 3.2 of the CTU packing guidelines, entitled "Packing and securing", states that the cargo in a CTU must be made secure to prevent cargo movement inside the unit. In addition, it is pointed out that the method of securing the cargo should not itself cause damage or deterioration to the cargo or the unit. A tight stow from wall to wall should also be sought where possible, if cargo of regular shape and size is loaded. Since void spaces cannot always be avoided, it is pointed out that the cargo should be appropriately secured by using dunnage, folded cardboard, airbags or other suitable means.

The best and most economical way of carrying cargoes is in box containers, if the cargo dimensions allow easy, tight packing of the containers with transit trays for motor vehicle components in a 20' box container.

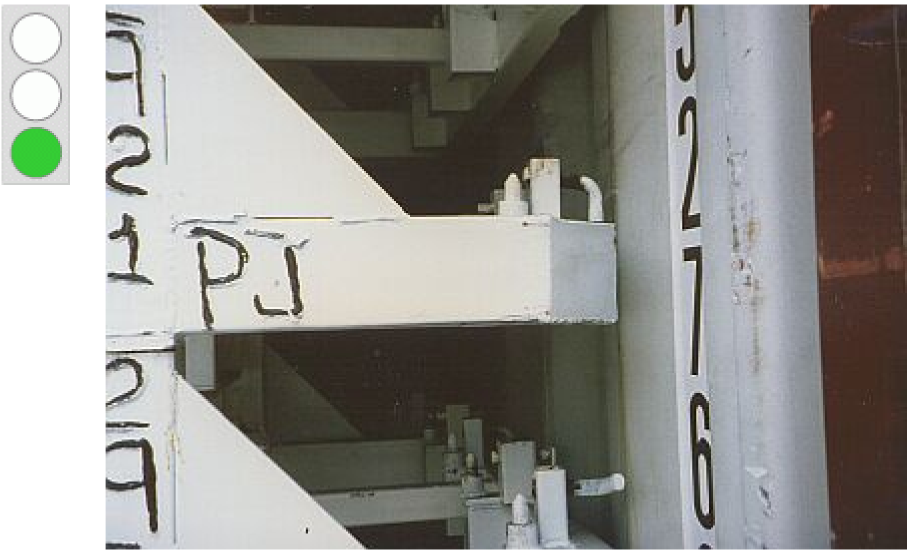
Transit trays for motor vehicle components in a 20' box container

In the stuffing example illustrated, the cargo is slightly narrower than the door opening. The door opening itself virtually matches the internal dimensions of the container . The trays for transporting motor vehicle components therefore fill the container almost completely. Since the trays interconnect, all that is needed for longitudinal securing in the door area is squared lumber or empty pallets.



Securing the container cargo in the door area

If such cargoes are loaded loosely stacked, gaps in the door area may be braced with wooden lattices, pallets or equivalent materials or simple structures. Any small gaps that may remain against the container side walls can be filled with boards, laths or the like.



Detail of the transit trays in the area of the container side walls

If package dimensions are not adapted closely enough to container dimensions, deficiencies regularly arise, which lead to cargo losses or greater labor costs and use of materials.

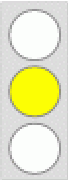
Unfavorable package dimensions can cause packing errors.

The telescope cartons should have been a few centimeters wider. Other aspects which merit criticism are the strapping with steel straps and the lack of edge protection. The bases of this combined packaging are only suitable for stacking if the tare weights are relatively low or the overstowed cargoes have adequate loading capacities.

Gaps in the cargo may result in damage.

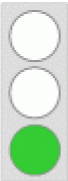
In transit, the small amount of play between the cargo and the container walls could result in damage to the packaging and possibly also to the contents.

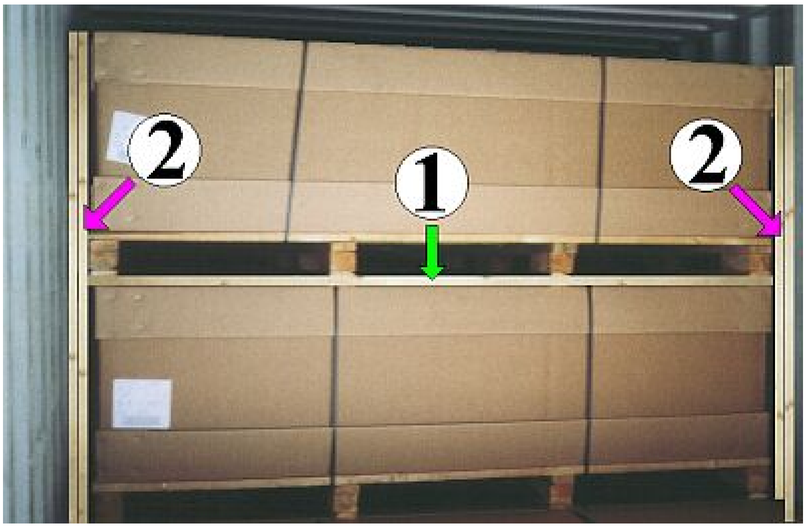
Lateral dunnage consisting of boards or similar materials can reduce possible play during carriage sufficiently to reduce the risk of damage.



Even provisional filling of the gaps reduces the risk of damage.

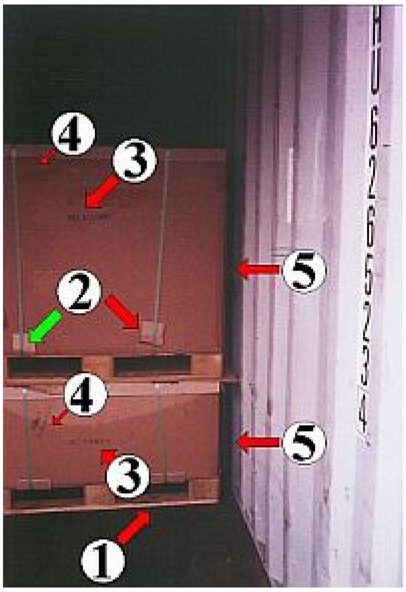
However, it is better to use interlayer dunnage to stop packages in the upper tiers from exerting any damaging pressure on cargo below them (1) and to rule out completely any sideways movement by using appropriately securely and firmly fitted materials (2).





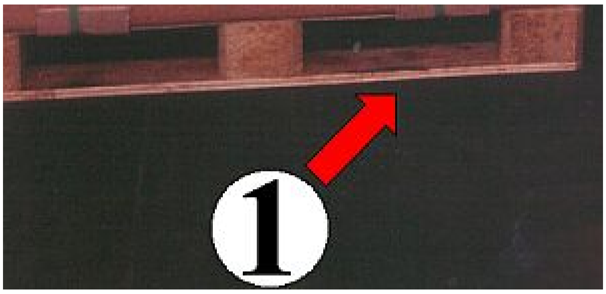
Compact stowage by filling all the voids

The packing example illustrated below is also deficient in certain respects:



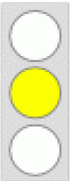
Inadequate packing in a 20' box container

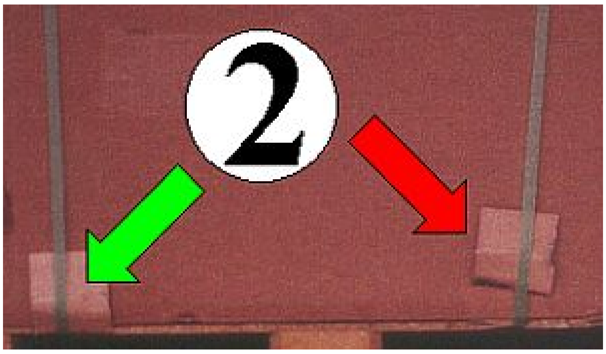
The pallet base used here is certainly an improvement on the previous example with the telescope cartons, since the different arrangement of the boards makes the contact area larger:



Sufficiently wide boards at the base of the pallet increase the contact area.

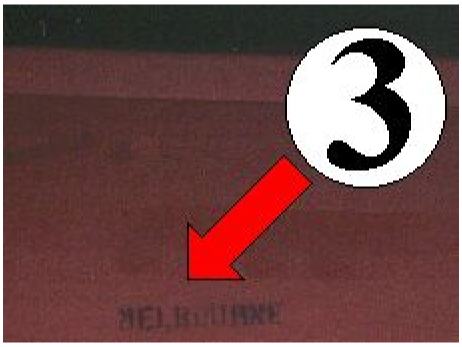
Steel straps are unsuitable for strapping cartons. The provisional edge protection is inadequate. It would be better to use wide plastic strapping with appropriate elasticity and sufficiently strong edge protectors:





Steel strapping and inadequate edge protection constitute a packaging risk.

The label on the package states that the container is bound for Melbourne. For voyages to Australia and New Zealand, it is essential to comply with regulations on the infestation of lumber by the Sirex wasp.



The CTU packing guidelines give the following general instructions:

> *3.3.2 If a CTU is destined for a country with wood treatment quarantine regulations, care should be taken that all wood in the unit, packaging and cargo complies with the regulations. It is a useful practice to place a copy of the wood treatment certificate in a conspicuous place inside and, where appropriate, outside the unit in a weatherproof pouch.*

It must be taken into account that any wooden components of the container and also introduced lumber must be treated or the entire container must be treated after packing. Included in this requirement are the container floor, any wooden liners, cargo securing lumber, pallets or pallet-like bases and also the lumber used inside combined packaging.

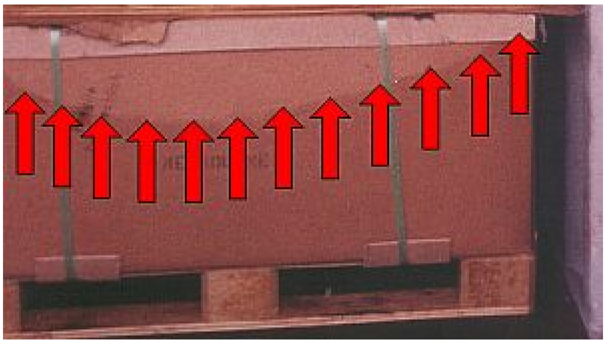
Marking often constitutes the only communication between the cargo shipper and the warehouse, packing and handling personnel. Labels on shipping packages should therefore be conspicuous and clear. The small characters used here for the marking "fragile" cannot be deemed adequate. Such markings generally relate to the package contents. The condition of the package gives the impression, however, that it is the packaging that is fragile here.

Inadequate marking of shipping packages

Where contents are fragile, clear labeling with an appropriate DIN or ISO symbol, i.e. an upright glass, is absolutely essential:

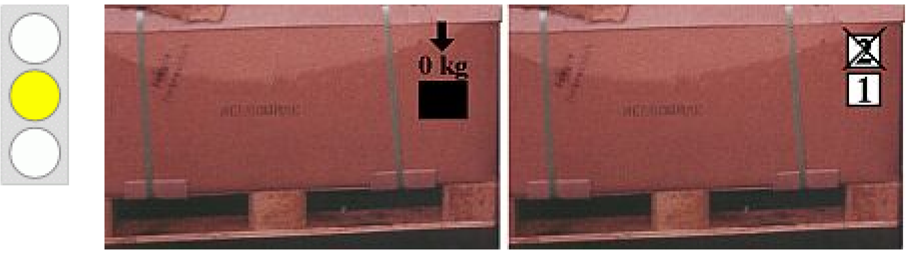
Symbol indicating fragile package contents

However, it is clear from the picture that the shipping package has already been bent, because the packaging was too weak, despite the provision of hardboard to distribute pressure and the fact that the package stowed over it was not excessively heavy.



Clear indication of weak and thus inadequate packaging

Although it would theoretically be possible to mark packages as weak using symbols forbidding overstowage, this is not really a practical suggestion as so much stowage space would be lost.



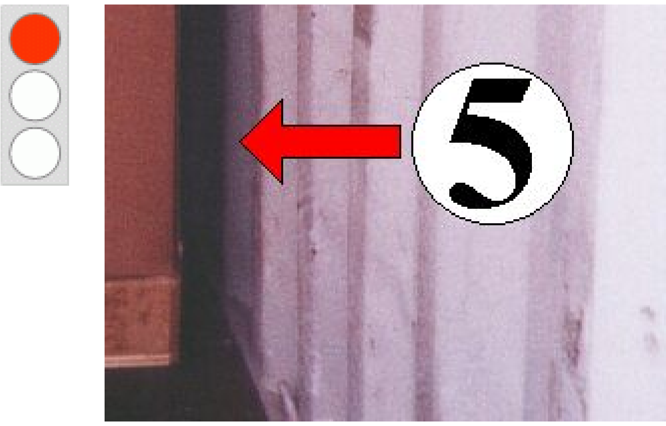
Theoretically possible symbols for "Do not overstow" or "Single-tier loading"

Packages should also be so constructed that they are able to withstand normal stacking loads in the means of transport used for carriage.

If the intention is to provide goods with particularly high levels of protection, it is best to use tested packaging or to have packaging which has been developed in-house tested by independent institutes.

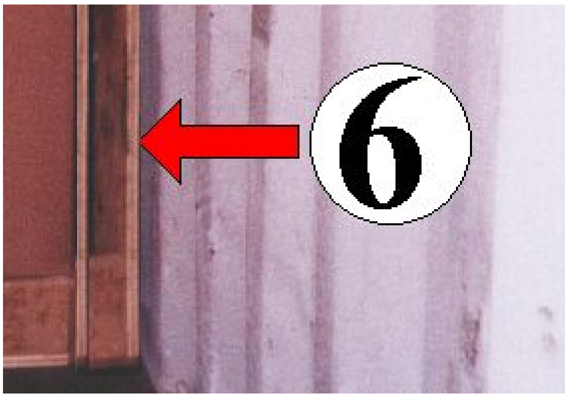
It is also possible to package normal goods in packaging whose strength or loading capacity is in line with the law on hazardous materials. The Annex to the IMDG Code contains regulations relating to stack pressure testing, which state that test packages which contain goods comparable to the original cargo should be stacked at least 3 m high. At the end of the test period, the packaging must neither lose its cargo nor deform or become unstable.. The minimum test period is generally twenty-four hours, though twenty-eight days is prescribed for certain packages. With the exception of bags, this stack pressure test is prescribed for all types of packaging.

Under no circumstances should gaps be left in the cargo during stowage, as they are the main cause of cargo damage.



Stowage gaps are the main cause of cargo damage.

The gaps must be filled. It is important to fill gaps with boards, squared lumber, pallets or similar materials using large bearing areas. If sensitive cargoes are being carried, large areas around the goods or packaging must be lined. With relatively heavy cargoes, large areas of lining are also necessary at the container walls. In the example illustrated, there was just room for a particularly thin pallet (6):



Filled gaps virtually guarantee transport without damage

Airbags are not suitable for such small gaps and load-securing foam is only suitable for rail and road transport due to its low "recovery".

5.2 Individual or homogeneous cargoes

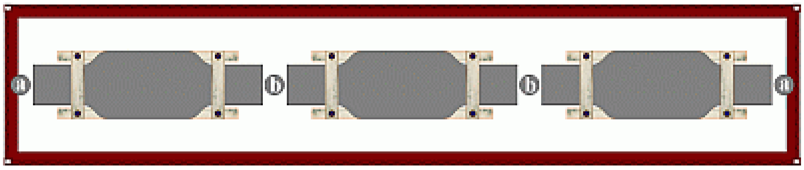
5.2.1 Castings, plant and machine parts

5.2.1.1 Cylindrical plant parts in wooden cradles

Example 1: Three plant parts on a 40' flatrack

A considerable amount of material was wasted securing the cargo lengthwise with wooden bracing. Although it looks expertly done, there are a number of deficiencies.

The gross weight of each of the three parts is stated as 7,366 kg. Thus, the total weight loaded on the flatrack is 22,098 kilograms, corresponding to normal forces of 7,226 daN per item or 21,678 daN for the whole cargo.



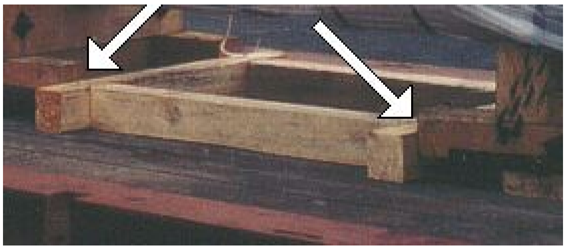
Basic diagram of the cargo

Taking the maximum possible lengthwise acceleration of shipment of 1 g as the basis for calculation and leaving possible frictional forces out of the consideration, the following securing forces must be produced in the lengthwise direction:

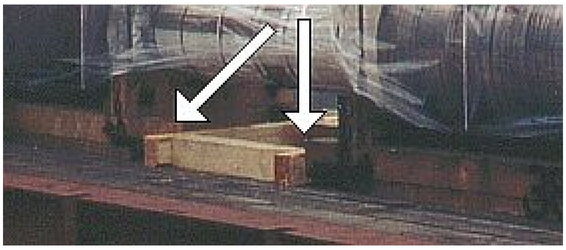
- at the end walls at (a) 3 x 7,226 daN = 21,678 daN;
- between the items of cargo (b) 2 x 7,226 daN = 14,452 daN.

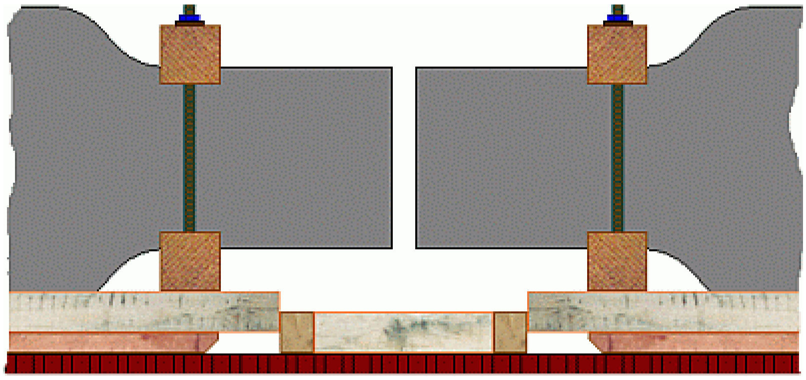
If the load bears on bracing lumber against the end grain, i.e. if the lumber is used end on to the grain, 100 daN per square centimeter of lumber cross-section may be expected. 217 cm² of effective lumber cross-sectional area would thus be required at points (a), and only 145 cm² at points (b).

If the load bears on bracing lumber against the face grain, i.e. if the lumber is used perpendicularly to the grain, 30 daN per square centimeter of lumber cross-section may be applied. The lumber cross-sectional area would accordingly have to be 723 cm² at points (a), and 482 cm² at points (b).



Above and right: incorrectly applied bracing means material wastage

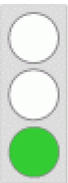


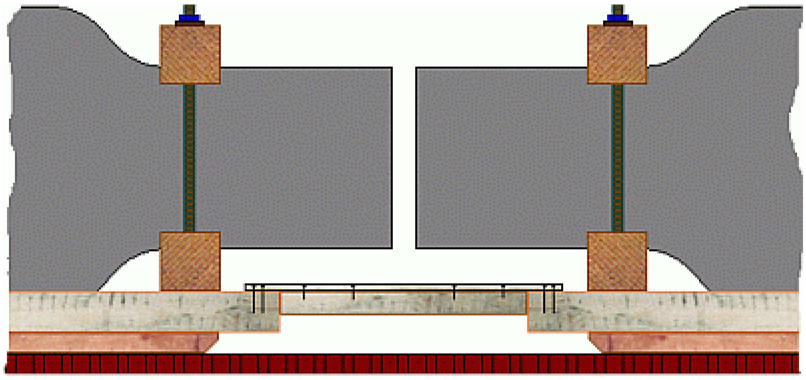


Basic diagram of the chosen bracing method

With the chosen method of bracing, wooden lengthwise members and crosspieces have been fitted on the flatrack floor between the plant parts' "wooden sled members" without taking account of their height.

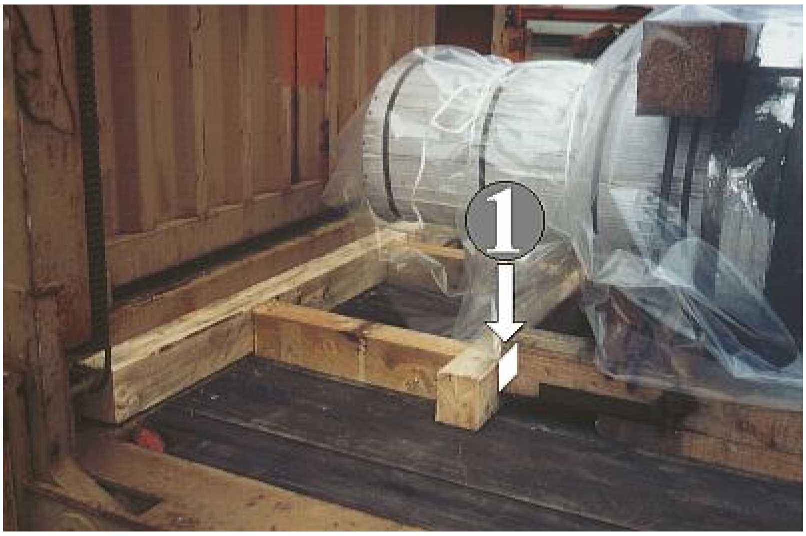
Using 14 x 14 cm lumber on the flatrack floor and the same size lumber for the higher "wooden sled members" of the plant parts results in a contact surface of only approx. 2 x 14 cm x 7 cm = 196 cm², so meaning that the cargo is inadequately secured. It is also unfavorable that crosspieces have been used which are stressed perpendicularly to the grain, despite the fact that the sled lumber is capable of bearing loads against the end grain. Appropriate securing could have been achieved with a quarter of the volume of lumber used.





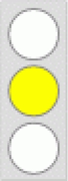
Cost-effective bracing

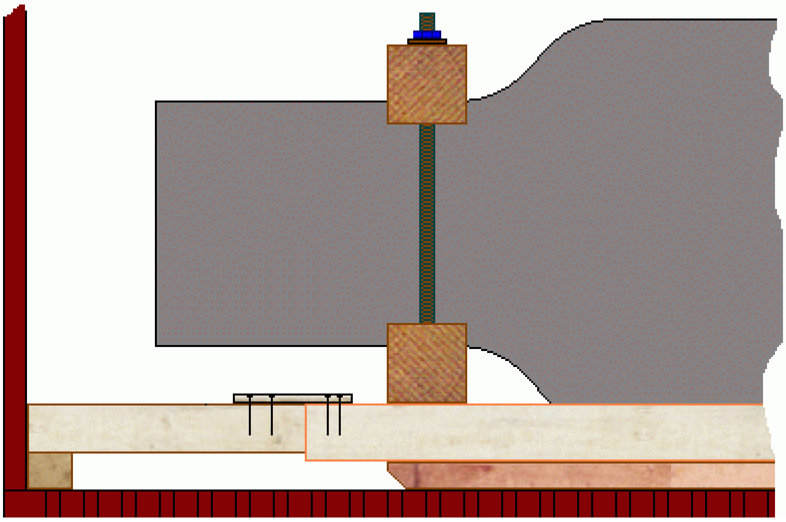
Since, when the lumber is exposed to stress against the end grain, an effective lumber cross-section of only 145 cm² is required to absorb 14,452 daN of longitudinal forces, two squared lumber members 8 cm x 10 cm nailed under a board and suspended from above and nailed to the wooden sled members would have sufficed.



Incorrect use of bracing lumber at the end of the flatrack

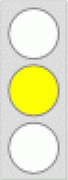
Some of the possible lumber loading capacity has also been wasted at the end, because the bracing has not be applied at the level of the wooden sled members, so making the effective lumber cross-sectional area smaller than was possible.

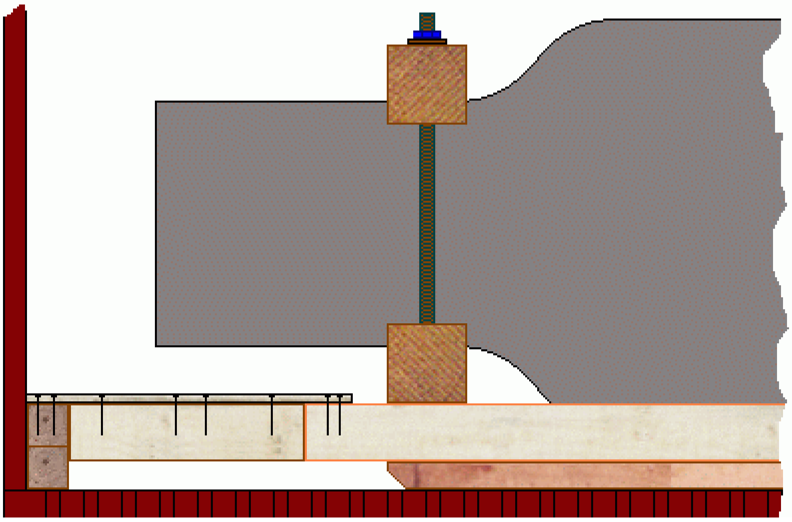




Possible bracing, provided that the front end wall has sufficient loading capacity

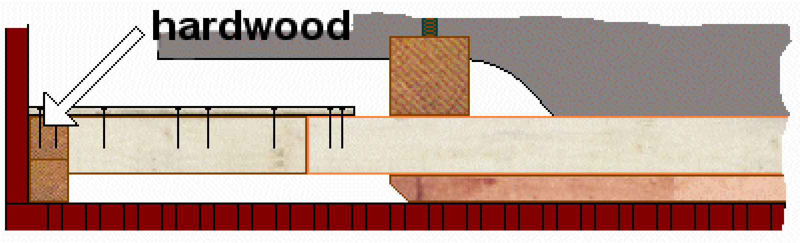
In order to be able to introduce forces of 21,678 daN into the front end wall, the wall must be capable of withstanding point loads at the appropriate places. If it is, the method illustrated may be used for cost-effective securing, since a lumber cross-sectional area of only 217 cm² is required and consequently of only 109 cm² per bracing member. Sufficient securing is achieved with only two 10 cm x 12 cm wooden members.





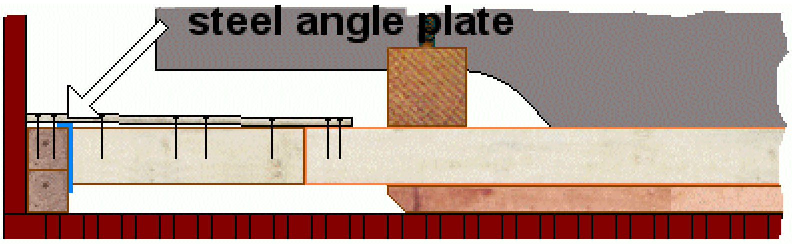
Bracing with pressure-distributing measures

If the front end wall is not able to withstand point loads, crosspieces must be fitted. Since the bracing members bear on the face grain of the crosspieces for pressure distribution, strength values of only 30 daN/ cm² must be assumed. Consequently, at 21,678 daN, a surface area of 723 cm² is required, or a cross-sectional area per member of 362 cm² if two members are used. Lumber 18 cm x 20 cm or with a similar cross-section would be necessary. In the packing example selected, this is impossible, since the sled lumber has a smaller cross-sectional area due its smaller size. As no changes can be made to the sled under the plant parts, there are three possible options:



Changing the strength of the lumber by using hardwood

The strength of the crosspieces may be increased by using hardwood beams. In the example described, it is sufficient for just the upper beam to be replaced by beech or oak.



Enlargement of the area by steel angle plates

Load transfer from the wooden bracing members loaded against the end grain and with a strength of 100 daN/ cm² to the 30 daN/ cm² crosspieces loaded against the face grain may be improved by fitting steel angle plates to increase the area for load transfer.

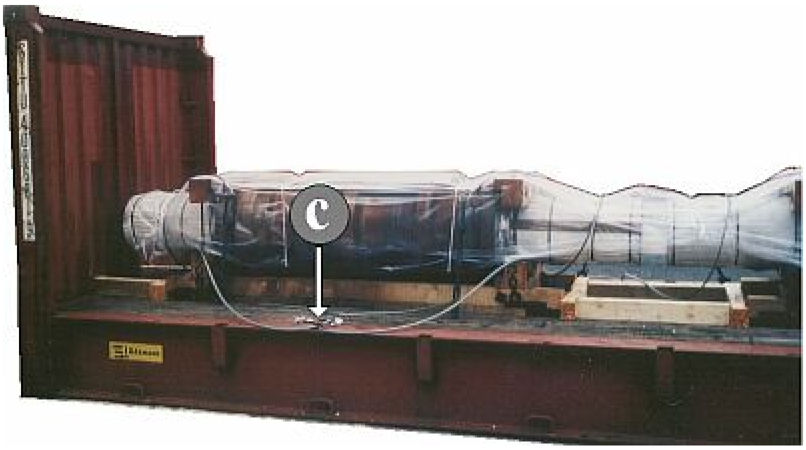
The third option is to transmit only a proportion of the longitudinal forces via wooden bracing and to absorb the remaining forces by means of lashing. This option has always to be considered when the front end wall of the container is insufficiently strong to absorb the necessary securing forces.

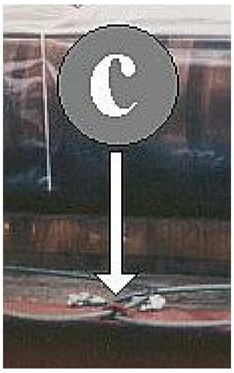
An "over-the-top" approach to securing

Here, much energy is being expended to secure the plant parts appropriately. Chain saws, steel wire ropes, wire clips, turnbuckles etc. have all been used, despite being unnecessary.

Preparation for cargo securing

The following pictures show that, despite all this effort, the objective has not been achieved:

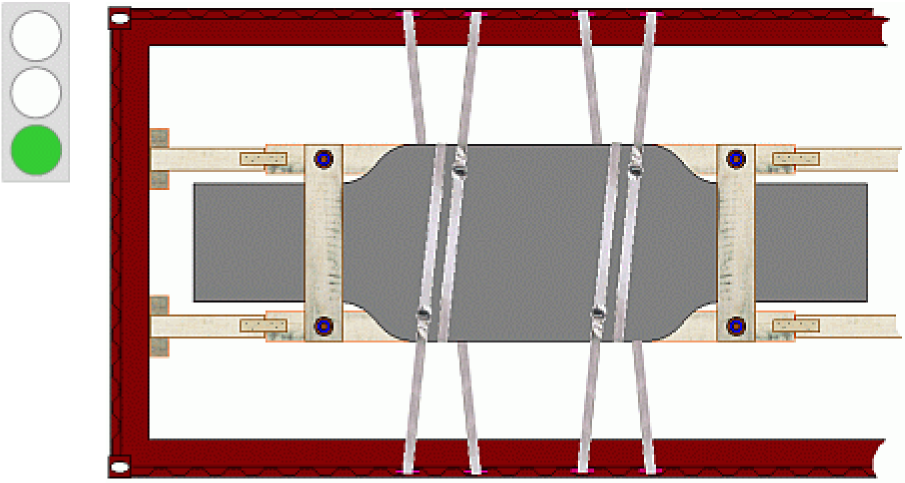




Top Above and selective enlargement to the left: Nonuniformity of lashings

Two steel ropes 16 mm in diameter, with which a maximum securing load per rope of 10,240 daN can be achieved in expert hands, are attached to lashing point (c), which can take a maximum securing load of approx. 3,000 daN. The intention was apparently to assist the obviously too small wooden bracing members by attaching the wires. They are intended to be effective in 3 directions: lengthwise, crosswise and vertically. The greatest attention is paid to the lengthwise component.

If sufficient wooden bracing is provided in the lengthwise direction, as already explained, sensible crosswise and vertical securing is lacking, a problem which can be readily solved with laterally acting loop lashings around the plant components. For this to be feasible, however, the nature of the cargo does have to allow the use of loop lashings.

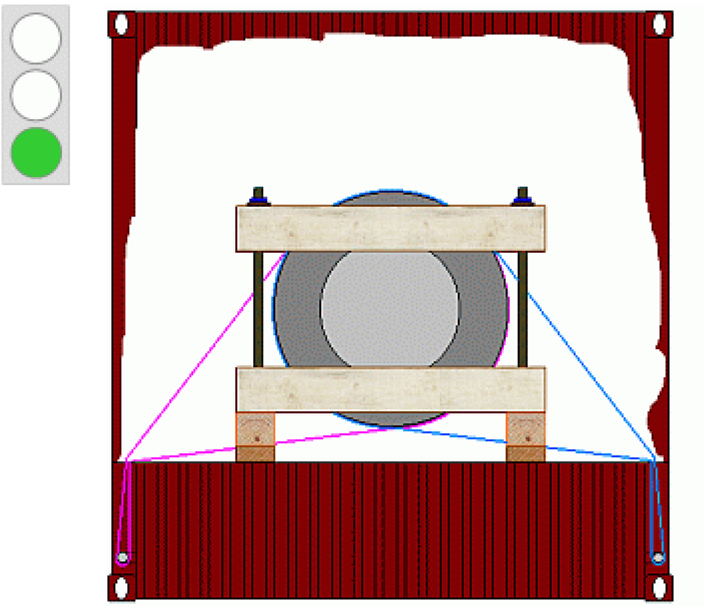


Crosswise and vertical securing by loop lashings, applied to separate lashing points.

In the case of a normal force of 7,226 daN per item, in the least favorable case transverse acceleration of 0.8 g and forces in the region of 5,780 daN have to be expected. The cargo dimensions result in average vertical lashing angles α of approx. 30°. The vertical component of a lashing thus amounts to approx. 50% and the horizontal component amounts to approx. 85% of the maximum securing load.

If single-use webbing belts with a maximum securing load of 2,000 daN are used, horizontal forces of 2 x 2 x 2,000 daN x 0.85 = 6,800 daN can consequently be achieved with the two loop lashings on each side. The vertical component of the four loop lashings then amounts to 8,000 daN, calculated from 4 x loop lashings each having two working parts x 0.5 for the lashing angle α x 2,000 daN maximum securing load.

In the example, the ends of the loop lashings are applied separately to different lashing points. It is assumed that the lashing points have a maximum securing load of at least 2,000 daN. The horizontal lashing angle β of approx. 12° should be disregarded, since a value of 0.995 is obtained for the cosine of 6° in accordance with the formula cos β/2. This reduction of 5 thousandths understandably does not need to be taken into account.

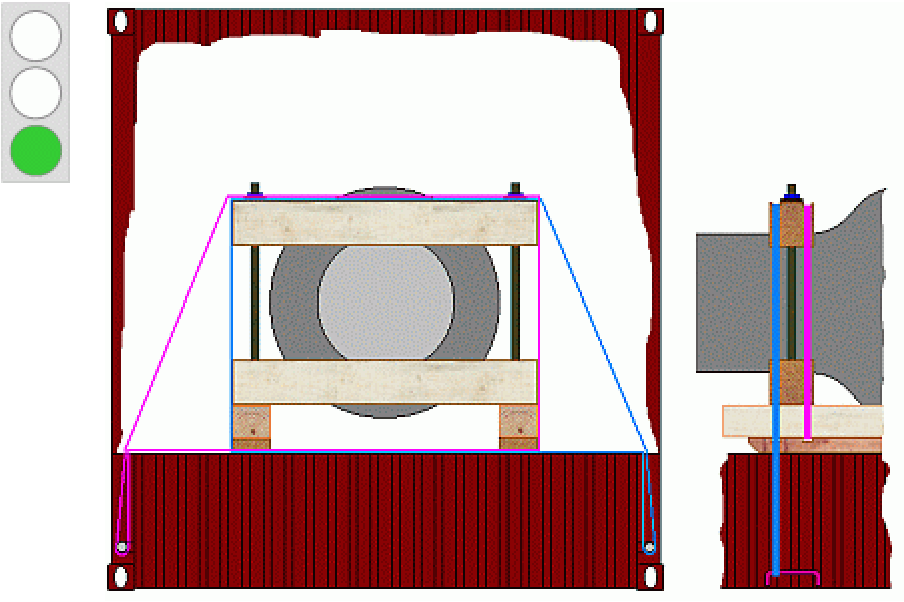


Crosswise and vertical securing by loop lashings, applied to a single lashing point

If the maximum securing loads of the available lashing points are at least twice that of the lashing materials used, the two ends of each loop lashing may be attached to one lashing point or guided around it.

Materials other than the above-mentioned single-use webbing belts can also be used for securing. However, any equipment used must be as economic as possible to use and not cause any damage to the shipping packages.

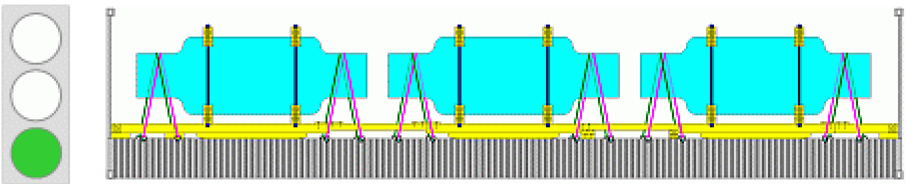
If the nature or sensitivity of a cargo forbids fastening to or around the cargo itself, securing may achieved by including the cradles, if they are as sufficiently strong as the components described above. This requires the cradles to be specially constructed, with routed grooves, recesses in the lumber or the like, but, if planned in good time, such measures do not involve excessive effort.



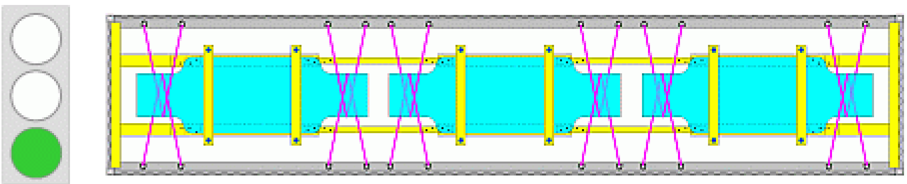
Crosswise and vertical securing by loop lashings passed around the cradles.

Since the above-described securing measures may damage the film applied to the packages, it is essential for cargo items which need to be kept dry to be provided subsequently with sufficiently tear-resistant protection against the weather, which must be applied in such a way that it cannot be damaged by wind forces during a voyage.

If the ends of the plant parts are capable of bearing a load, they may be secured with loop lashings. The advantage of this is that the smaller diameters result in more favorable transverse components:

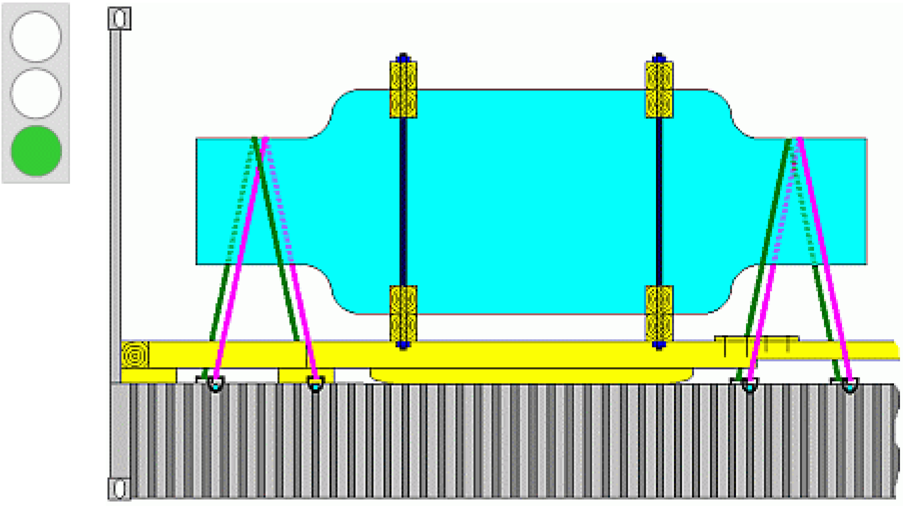


Securing at the ends of plant parts - side view

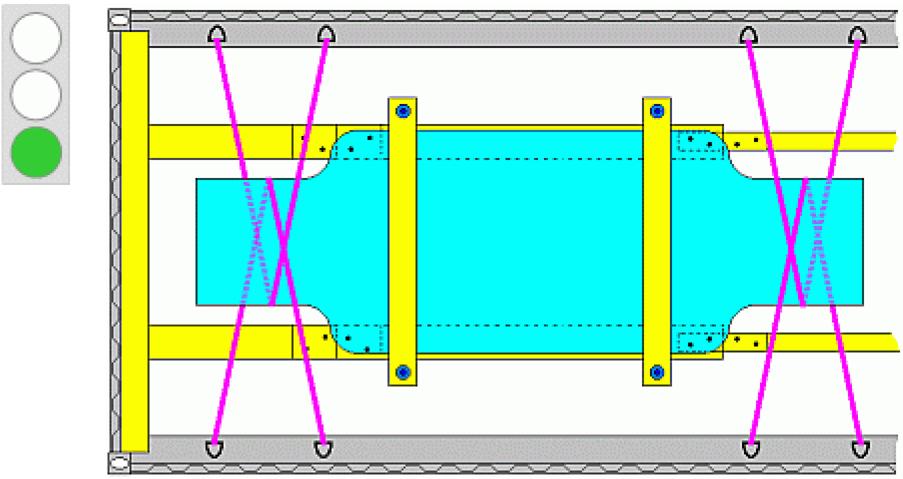


Securing at the ends of plant parts - plan view

The path taken by the loop lashings is more clearly visible in the following Figures:



Securing at the ends of plant parts - detailed side view



Securing at the ends of plant parts - detailed plan view

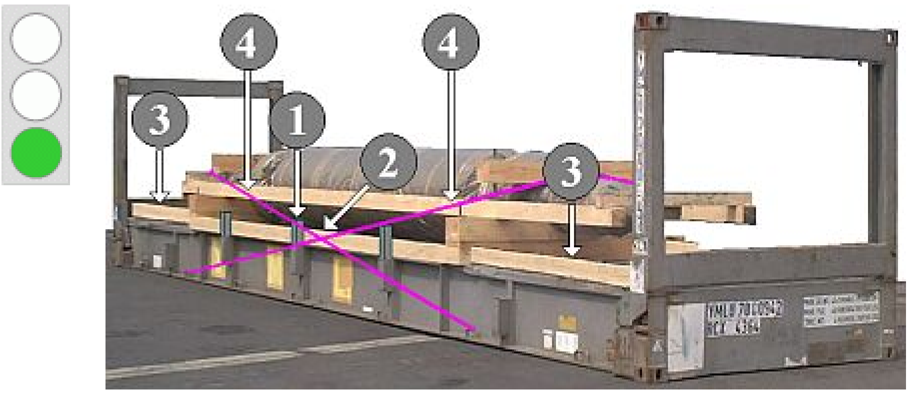
5.2.1.2 Cylindrical plant parts in wooden frames

Example: Plant part in a wooden cradle on a 40' collapsible flatrack

Plant part in a wooden cradle - not yet secured

The roll-like plant part lies in a cradle attached to the forwardly and rearwardly tapering ends by threaded rods in the form of "pipe clamps". Interconnection is effected only by the two lengthwise wooden members, which are fitted laterally at the bottom. The upper frame consists of two lengthwise wooden members and two wooden crosspieces, which are simply nailed. This alone is not adequate to hold the part secure in the cradle.

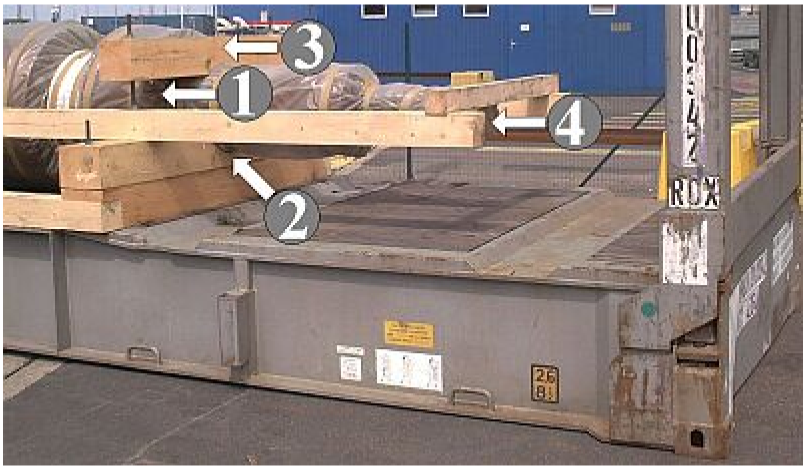
This picture shows how satisfactory securing can be achieved:



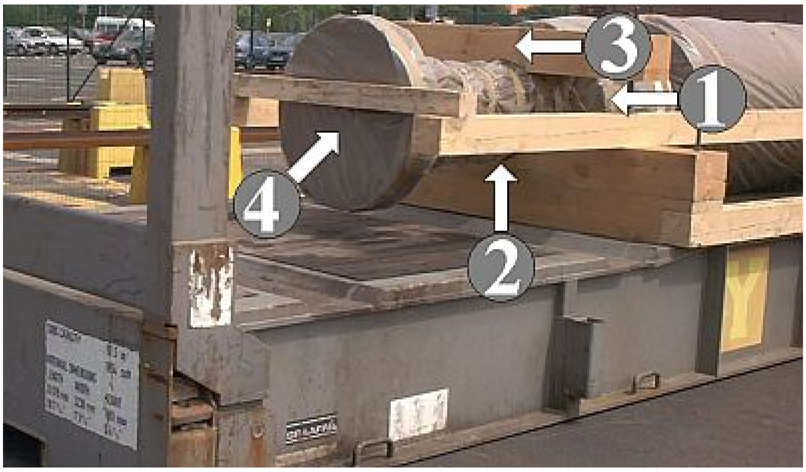
Plant part in a wooden cradle - secured

The flatrack used being one with stanchion pockets, three stanchions (1) should be inserted on each longitudinal side (merely indicated in the picture). If no stanchions are available, appropriate steel profiles or steel girders should be used. It is absolutely necessary for three squared lumber members to be fitted in the base frame transversely relative to the stanchion positions (2), so that the cradle is stabilized in the base area and held secure in the crosswise direction by the stanchions or steel profiles . Corresponding lengthwise securing of the cradles in the base area should be achieved by using longitudinally positioned squared lumber members (3). The wooden members illustrated need to be conformed to the weight of the package and possibly X-braced with boards. The top crosspieces of the "pipe clamps" need to be fixed lengthwise with loop lashings (4) in such a way that the plant part is secured in its cradle.

If the factory-fitted cradle is studied carefully, it will become apparent that other options for lengthwise securing might be possible, provided that information about the loading capacity of the plant parts is provided by or can be obtained from the manufacturer.



Cradle of the package at one end



Package cradle viewed from other end

If the bearing (1) is loadable in the lengthwise direction, the crosspieces (2) and (3) could be reinforced by means of horizontally fitted oblique bracing against the corner posts of the flatrack. If the shaft and shaft flange (4) were loadable in the lengthwise direction, oblique bracing could be positioned from that point horizontally against the corner posts of the flatrack.

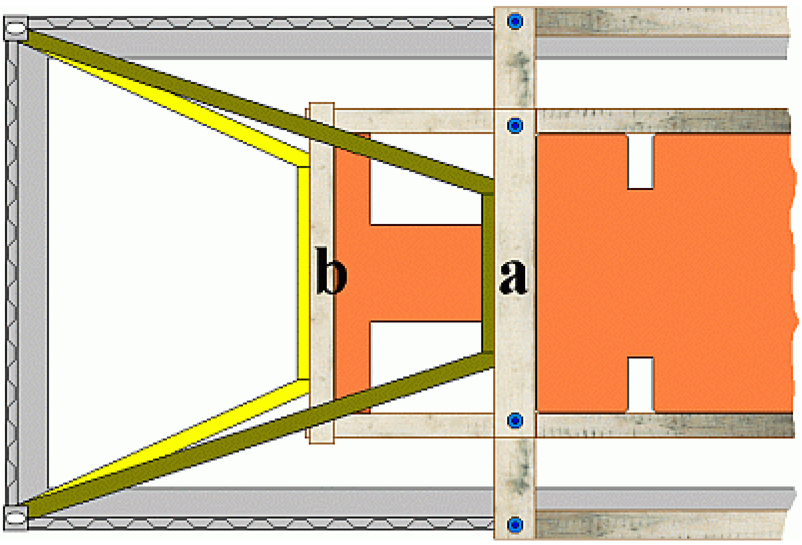
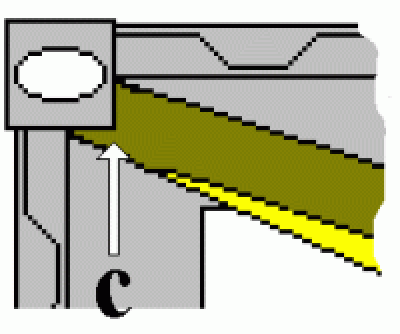


Diagram showing the principle of oblique bracing between the bearing struts (a) or the end flange (b) and the corner posts in flatracks without a fixed end wall



"Bird's mouth" in the wooden members for the corner posts

So as to be able to transmit the force to the corner posts, so-called "birds' mouths" have to be cut into the squared lumber members which bear on the corner posts.

When using flatracks with fixed end walls, horizontal bracing could be fitted against the end walls of the flatrack, using wooden members for pressure distribution.

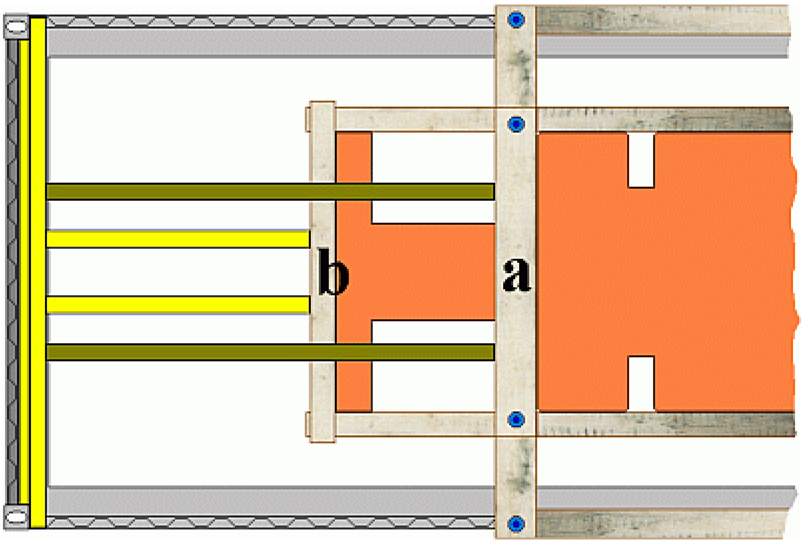
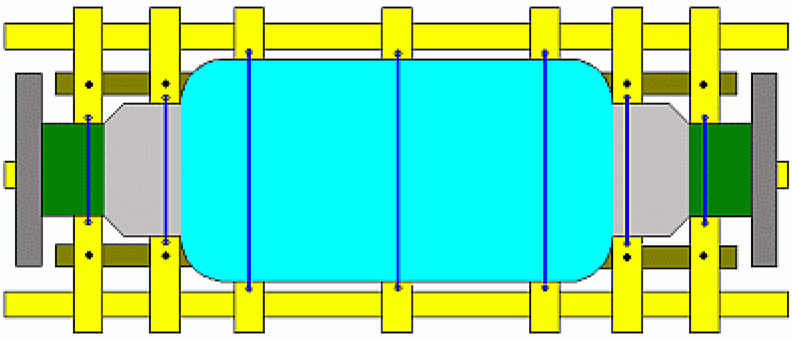


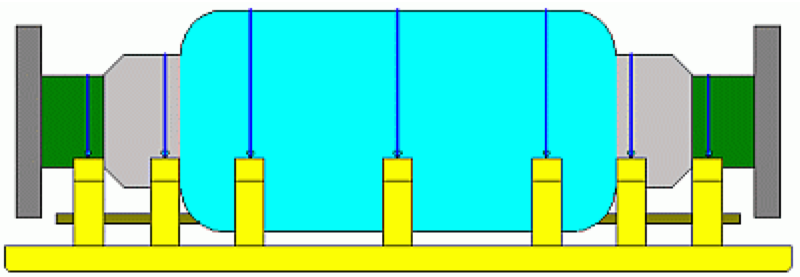
Diagram showing the principle of horizontal bracing between the bearing struts (a) or the end flange (b) and the flatrack end wall

It should be possible to prevent damage by simultaneously securing both static and rotating parts of the plant. Individuals involved in providing cargo securing who are not well versed in mechanical engineering are not in a position to assess technical features accurately. It is therefore essential that the manufacturers provide information about the loading capacities of plant components beforehand or at the very latest on delivery to the container packing company, so that only admissible securing measures are used and inadmissible measures are not carried out.

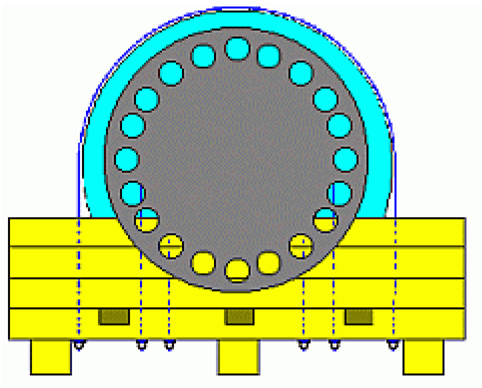
The following drawings are just suggestions; for instance cradles and securing for roller-, shaft- or turbine-like parts could look like this:



Cradle for a plant part - plan view

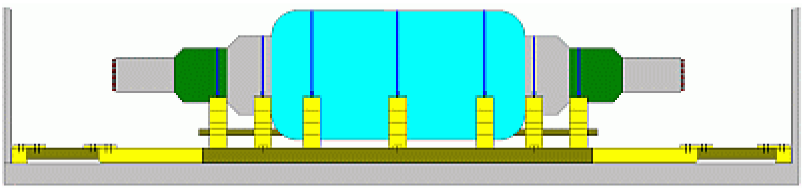


Cradle for a plant part - side view



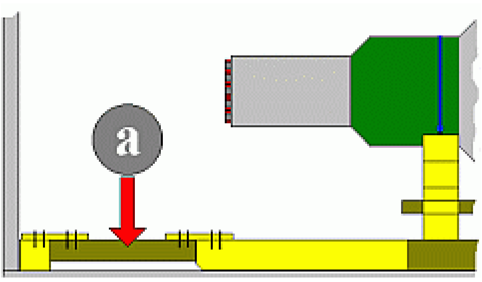
Cradle for a plant part - end-on view

Such a part could be secured like this on a flatrack or in a container or similar transport receptacle:



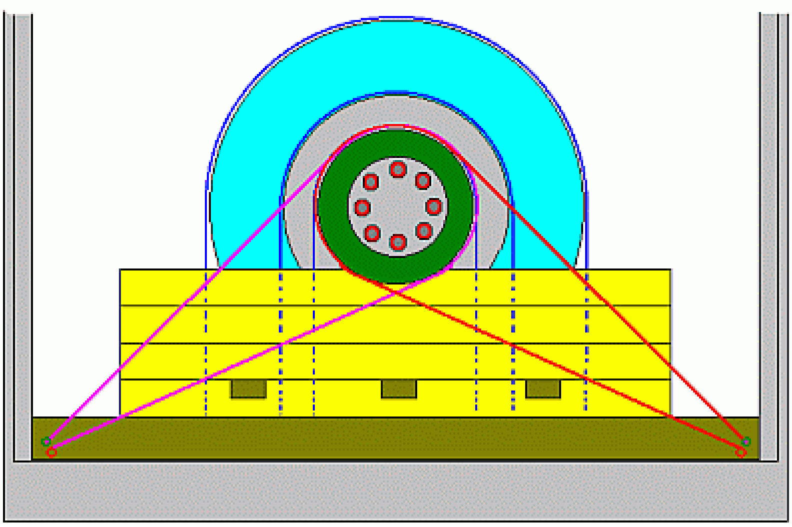
Lengthwise securing using wooden bracing

To distribute pressure, crosspieces are fitted to the end walls of the container or CTU. The remaining gap between them and the lengthwise members of the cradle is secured with "suspended" squared lumber (a):

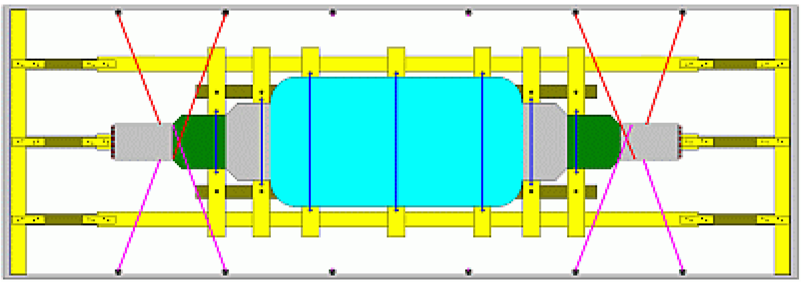


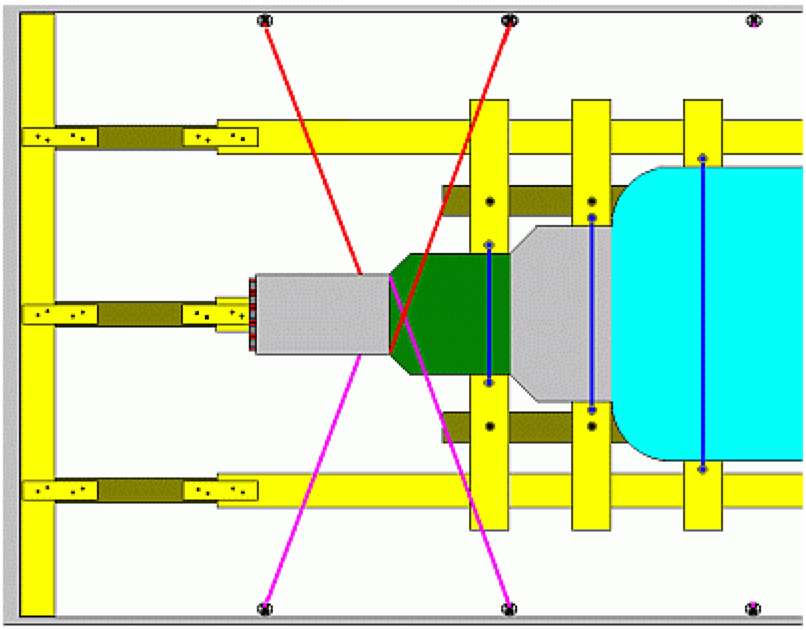
"Suspended" squared lumber for lengthwise securing

Lateral securing may be achieved with loop lashings over areas of the plant part with an adequate loading capacity, the loop lashings having favorably dimensioned horizontal transverse components and also sufficiently large vertical components. The vertical components are not intended here to act as tie-down lashing but rather to hold the plant part in the cradle even in the event of extreme heel angles.

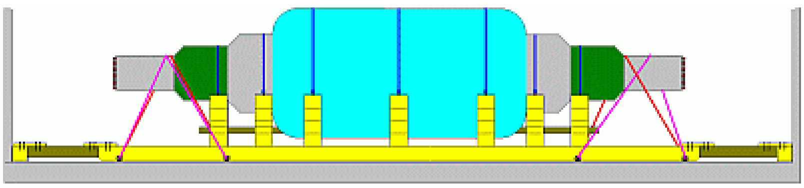


Lateral securing using loop lashings - end-on view





Top and selective enlargement below:
Lateral securing using loop lashings - plan view



Lateral securing using loop lashings - side view

Example: Unknown plant part on a 40' flatrack

Plant part on 40' flatrack

Securing with tie-down lashings

The type of cargo and its weight are not known. It can definitely be assumed that the six fitted tie-down lashings made from webbing cannot constitute adequate cargo securing. They have been only very slightly pretensioned and could not therefore produce frictional forces of sufficient magnitude. The single-use webbing belts have been pretensioned with a special tool. Subsequent re-tensioning is not possible, or only with considerable effort. All the buckle closures were on one side, i.e. it was unilaterally pretensioned. In addition, the shipping package is slightly overwidth, which rules out securing with tie-down lashing from the outset .
Woven tarpaulins with a net stretched over them are provided for protection against the weather; they are satisfactory but should have been secured more carefully, especially in the end wall area of the plant part.

5.2.1.3 Heavy plant part on 40' flatrack

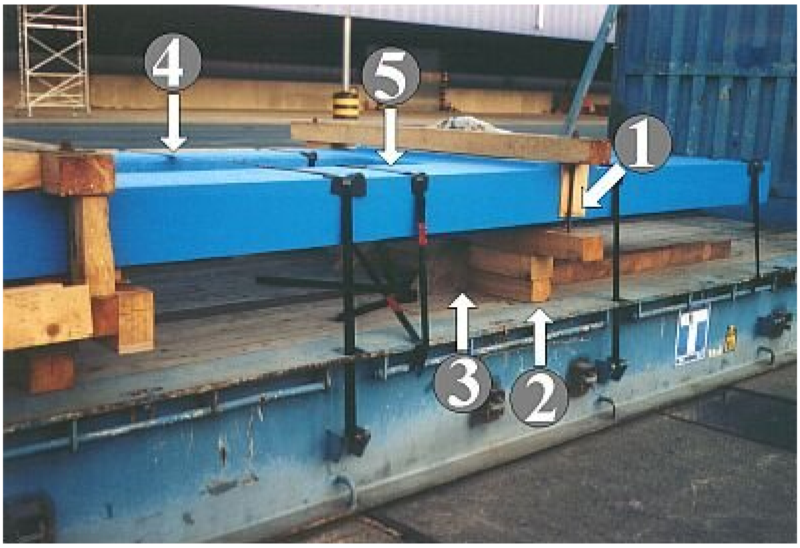
Example: Plant part on a 40' flatrack

Inadequately secured plant part

In this instance, a lot of work and material have gone into securing which will not withstand the shipping stresses which may arise. The transverse securing consists of steel strapping, mostly fitted in the form of tie-down lashings. The nailed-down wedges which are intended to effect lengthwise securing are a waste, since they are incapable of performing their task.

The wedges cannot withstand the longitudinal forces which are to be expected.

Although the item of cargo is not excessively heavy, it does nonetheless weigh 8,750 kg. A positive feature is that the wedges have been correctly cut. Nailing into the face grain is possible.



The item of cargo is supported under the struts (1) by crosspieces (2) which are (should be) secured by wedges (3) against tipping in the lengthwise direction. As has already been mentioned, the use of steel strapping as tie-down lashing (4) is problematic. The use of steel strapping as direct lashing (5) is better, although it was applied here in a somewhat unfavorable manner.

If it is assumed that the cargo will be exposed to the highest possible transport stresses in combined road/rail/sea transport operations, the following horizontal stresses should be expected, without taking account of frictional forces:

- lengthwise: 8,584 daN normal force at 1.0 g = 8,584 daN
- crosswise: 8,584 daN normal force at 0.8 g = 6,867 daN

When bracing with squared lumber in the lengthwise direction, 86 cm² of lumber cross-sectional area are necessary if the lumber is loaded against the end grain or 286 cm² if the load is against the face grain. The same lumber cross-sectional area is necessary for an appropriate base structure.

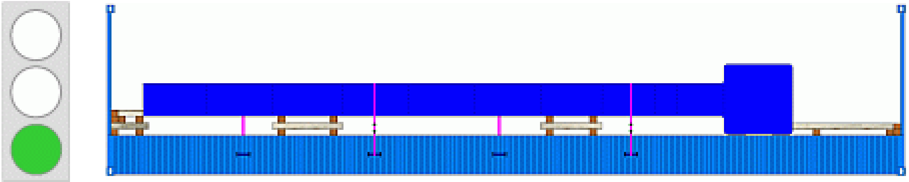


Diagram showing the principle of appropriate securing - side view

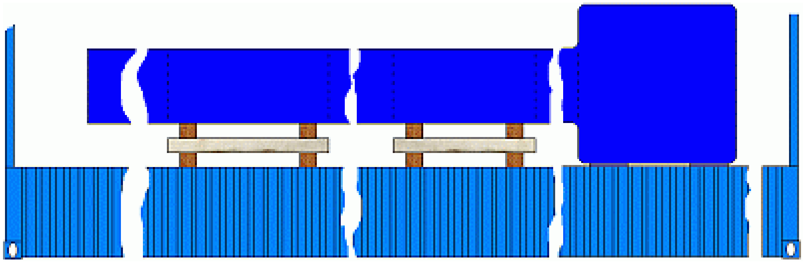
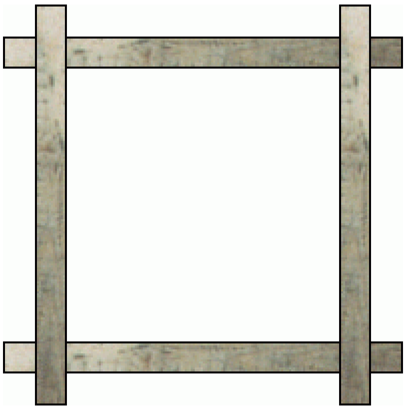
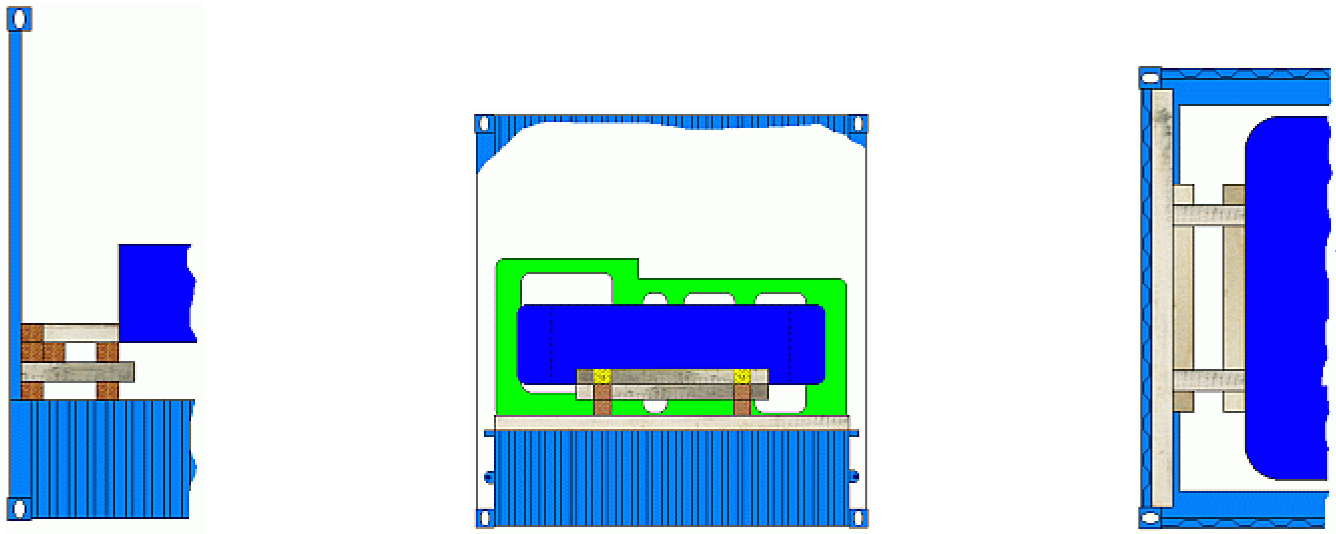


Diagram showing the principle of using cross-over beds as a base structure - side view

Since two cross-over beds provide a total of eight cross-over points, simple wooden beams with an edge length of 6 cm would suffice for supporting the steel part from below.

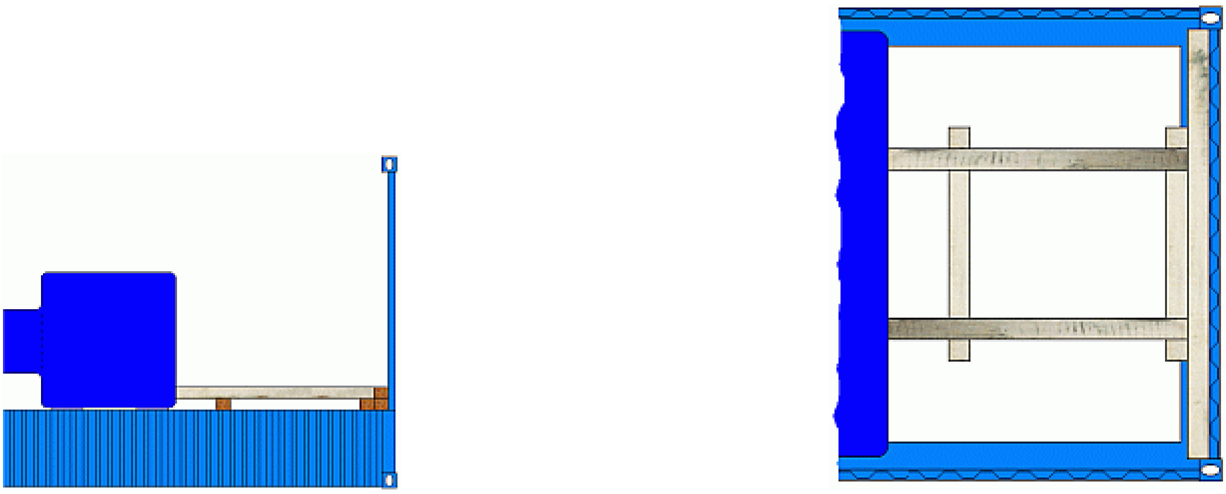


Cross-over bed in plan view

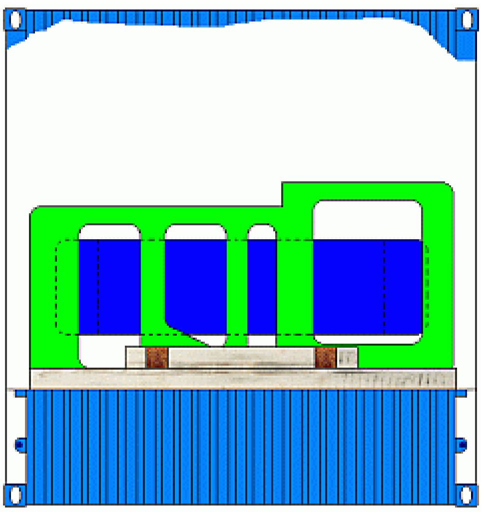


Bracing of the narrow side of the part in side, end and plan view

The variant shown is only a suggestion. Raising of the active squared lumber in the top layer can also be achieved by nailing planks to one another in steps, or by other similar methods. The other examples relating to wooden bracing contain a range of suggestions. When using two wooden members as longitudinal struts, they need to be at least 12 cm x 12 cm in size. If 10 cm x 10 cm wooden members are used, three are needed . The same minimum lumber thicknesses apply for bracing the other side.

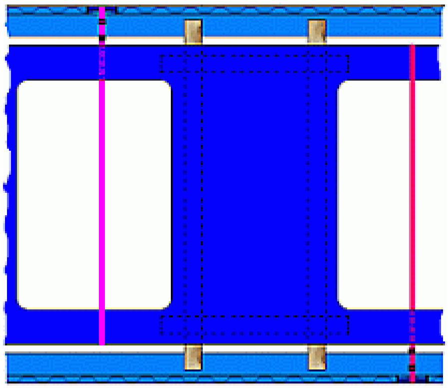


Bracing of the broad side of the plant part in side and plan view

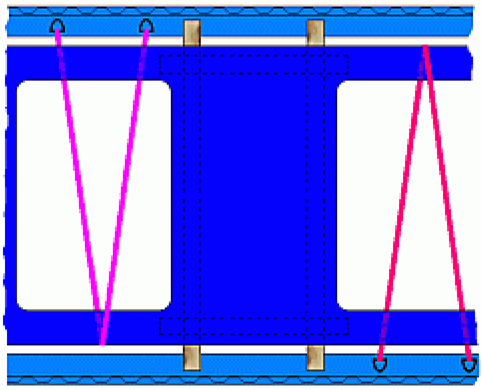


Bracing of the broad side of the plant part in end-on view

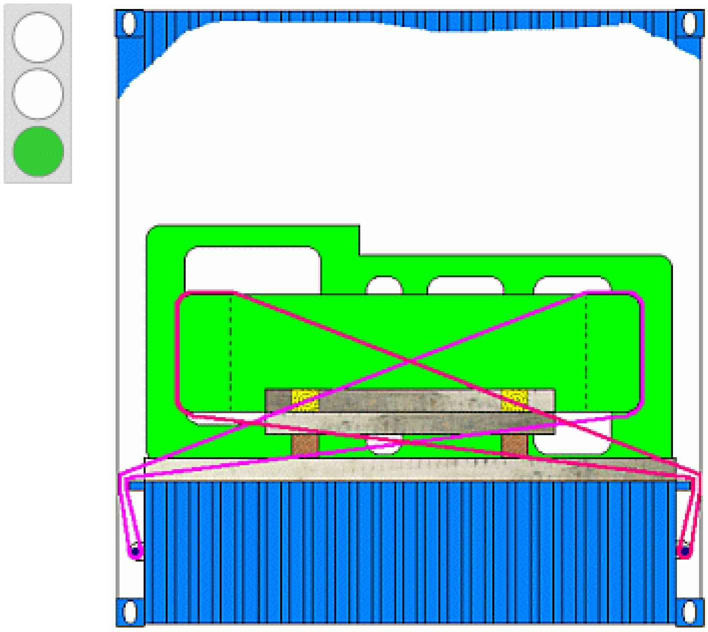
Appropriate transverse securing can be readily achieved using loop lashings, which are arranged around the opposite beam of the plant part from the lashing point(s), the question of whether the ends of the loop lashings are applied to one lashing point or two being dependent on the maximum securing loads of the lashing materials and points used.



One lashing point per loop lashing

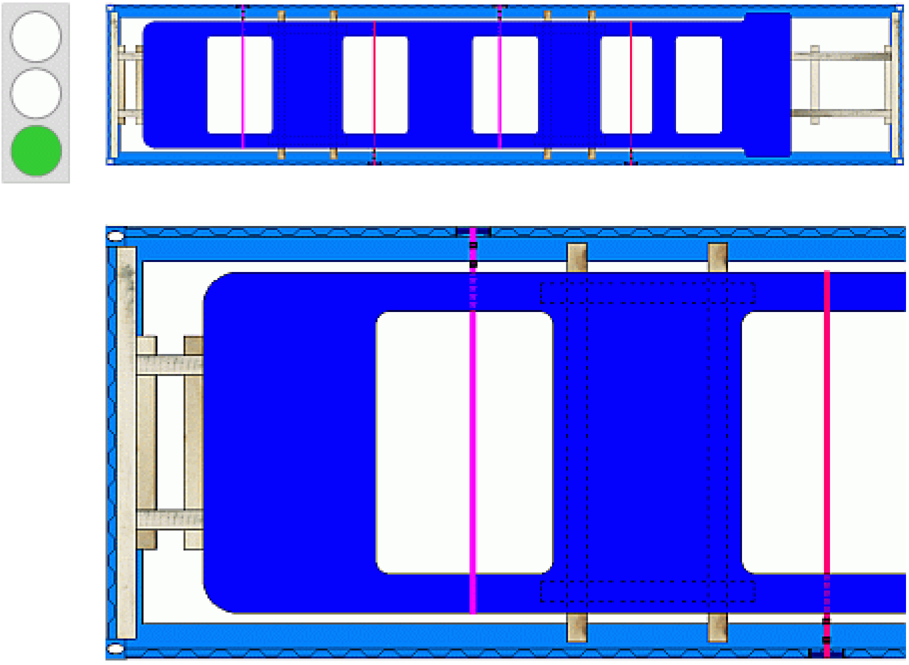


Two lashing points per loop lashing

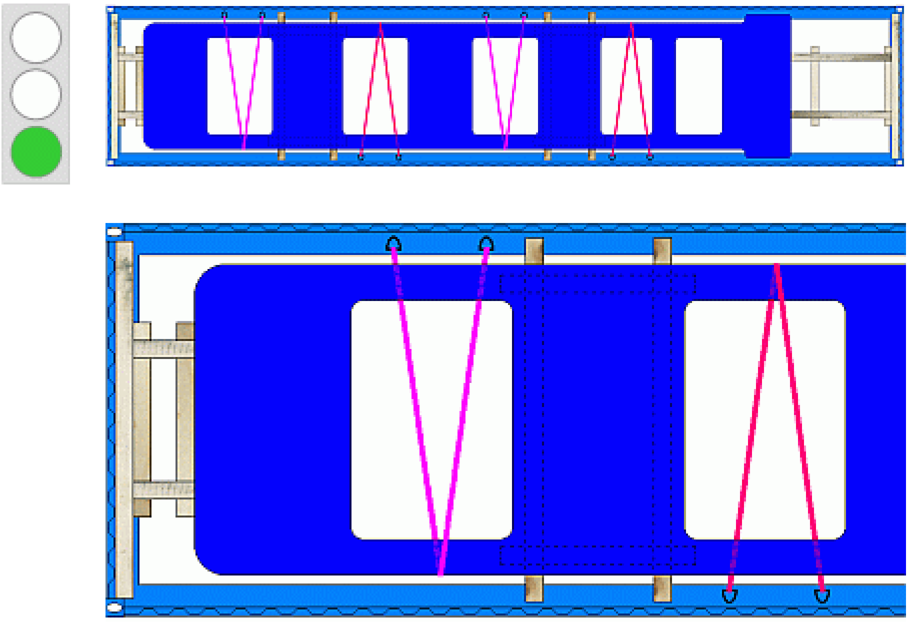


Arrangement of loop lashings in end-on view

If the various methods are selected, the securing looks like this overall:



Top and selective enlargement below:
Securing with wooden bracing in the lengthwise direction and two loop lashings to the sides.
Loop lashing ends applied to one lashing point.

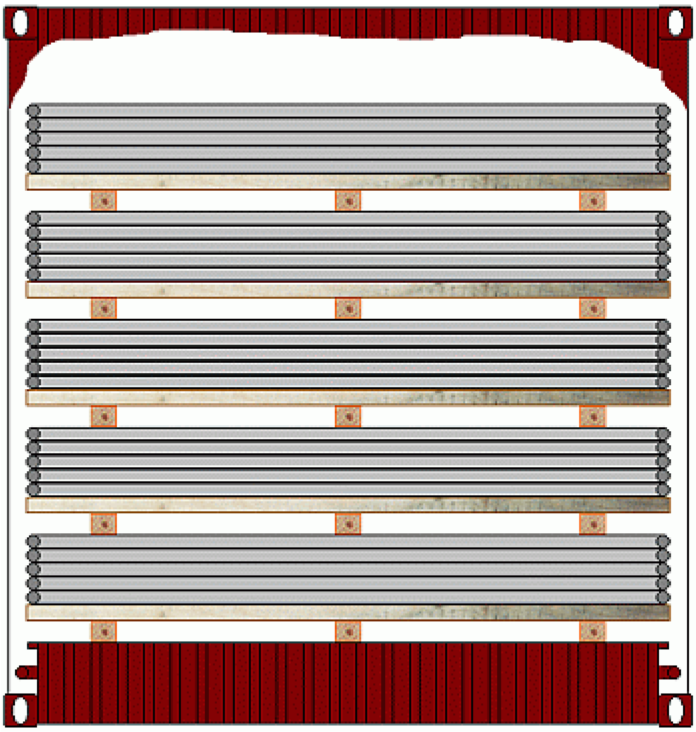


Top and selective enlargement below:
Securing with wooden bracing in the lengthwise direction and two loop lashings to the sides.
Loop lashing ends applied to two separate lashing points.

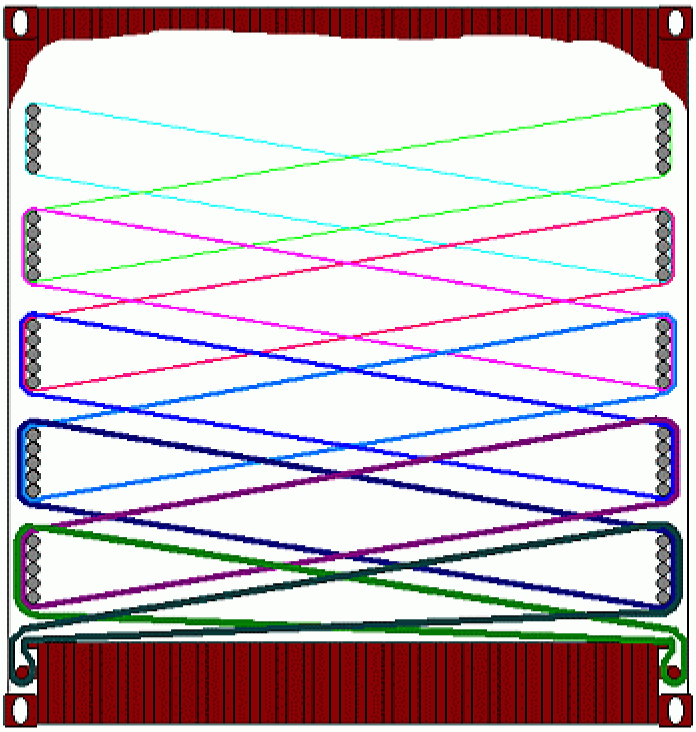
5.2.1.4 Pipe frame on 20' flatrack

Steel pipe structures on a 20' flatrack

Pipe or lattice structures can virtually always be secured from the opposite side using loop lashings. Since the angle becomes less favorable as the height of the cargo increases, the cargo can be secured directly to the cargo stowed below it and ultimately to the flatrack itself.

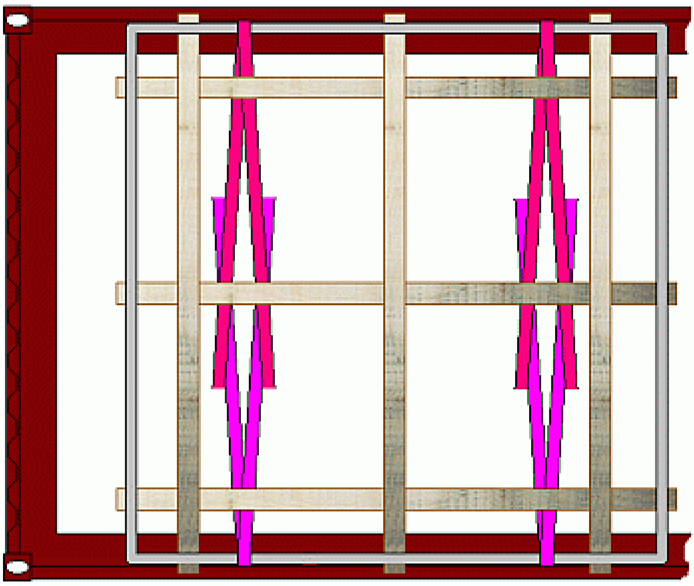


Principle of stowage - end-on view

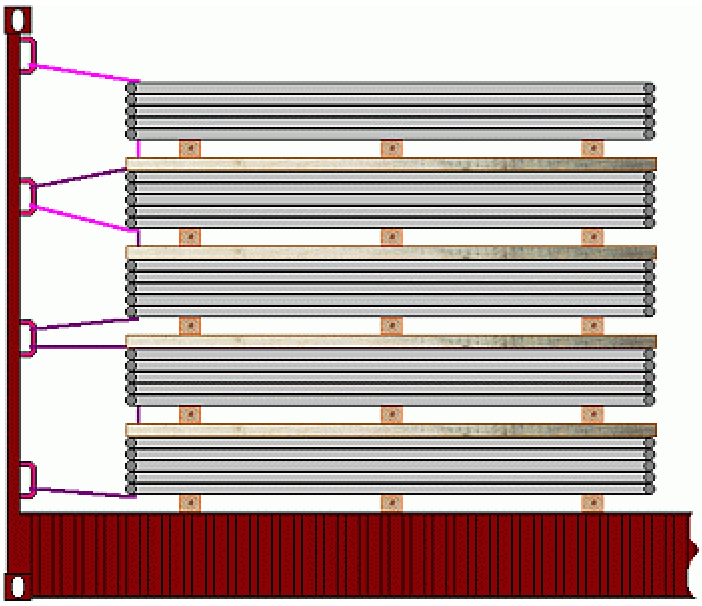


Principle of securing in end-on view

To make the illustration a little clearer, only the outer pipe frames have been shown. Lower down, the strength or number of securing means increases in relation to the increasing cargo mass. The principle could also be described as piggy-back securing, as each part of the cargo takes the next on its back.

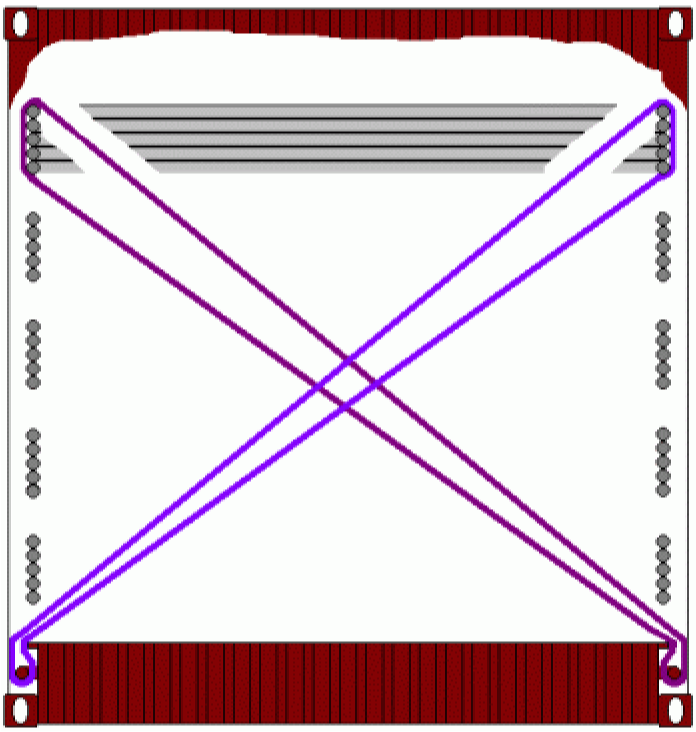


Principle of securing one layer in plan view



Principle of securing at front

Whether the entire cargo block or only individual parts are lashed to the end walls (or the next stack) depends on the maximum securing load of the lashing points, the securing materials available and the mass of the cargo. It goes without saying that blocking may also be used in the lengthwise direction. Lateral blocking is also an option in the case of flatracks with stanchions. Depending on the mass of the cargo, additional cross lashing may be incorporated.



Additional cross lashing for stabilization

To clarify the securing principle, only the outer edges of the "pipe bundles" and part of the top stack have been shown.

5.2.1.5 Overheight, overwidth plant

Plant part on 20' flatrack

Inadequately secured plant part on a 20' flatrack

Such plant parts can only be adequately secured when they are so firmly bolted to the wooden bed that only the wooden bed itself needs to be secured. The weather protection fitted would be inadequate for carriage on a normal container ship, but this flatrack is intended for carriage below deck on a ro/ro ship.

Inadequate lengthwise securing at one end

Three nailed wedges are not up to preventing the plant part from moving in a lengthwise direction.

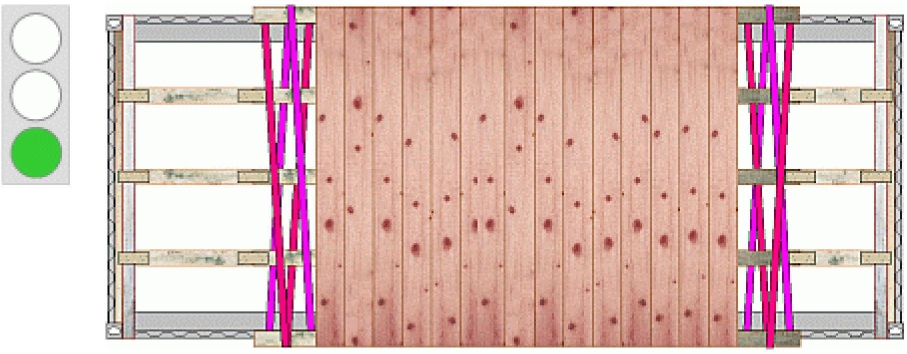
Inadequate lengthwise securing at the other end

It is more than optimistic to hope to prevent leftward movement of the heavy plant part with a relatively weak plywood case, and the lashing belt used to secure the plywood case (which has already deformed the case) deserves no further comment.

Wooden bracing covering the area of the bed to which the plant part is bolted would provide appropriate lengthwise securing. The appearance of such wooden bracing has already been sufficiently described. As the bed is overwidth, and the lengthwise members of the bed are completely covered with transverse planks, transverse securing using lashing means is not feasible or can only be achieved with corresponding additional effort.

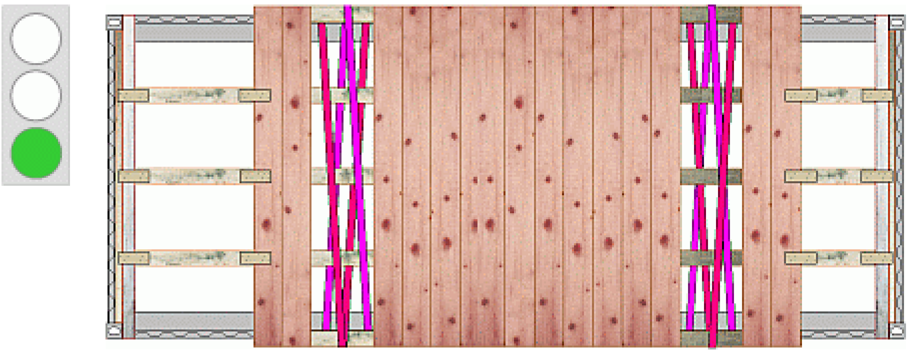
Since the flatrack has stanchion pockets, the bed could be secured laterally using specially shaped stanchions, or appropriately sized case restraint shoes could be set in place before loading to achieve a tight fit between flatrack floor and plant part bed.

Leaving out two transverse planks at the bed ends would have made securing by loop lashings possible.



Lengthwise securing using wooden bracing
Transverse securing using loop lashings passed around the bed at the ends, around the lengthwise bed members

Greater flexural strength could be achieved in the bed for securing purposes if the structure of the plant part allows planks to be omitted not absolutely at the ends but within the surface of the bed.



Lengthwise securing using wooden bracing
Transverse securing using loop lashings passed around the lengthwise bed members within the bed

To achieve either variant, the lengthwise members of the bed must be firred to such a degree that the lashing means can be passed through without difficulty.

Firring of the lengthwise bed members, so that the lashing means can be passed through

If the plant part itself had load-carrying fastening points, lateral securing could be achieved using direct lashings attached to them. However, care should be always be taken in the case of overwidth cargoes, as is the case here.

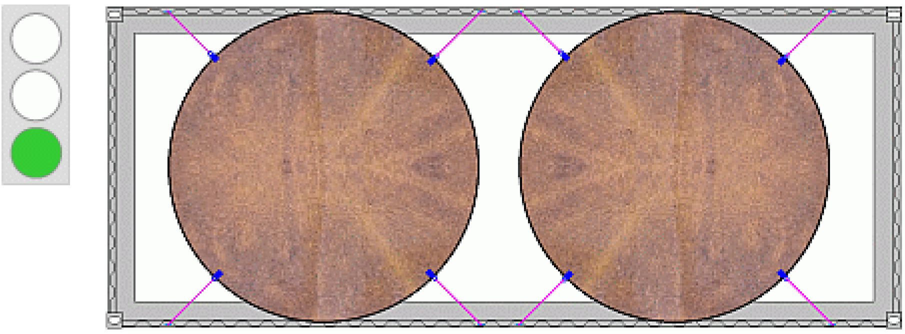
In this case, tie-down lashings, here constituting direct lashings, are suitable for vertical securing of the plant part.

5.2.1.6 Half-shells

Half-shells on a 20' flatrack

Inadequate securing of half-shells on a 20' flatrack

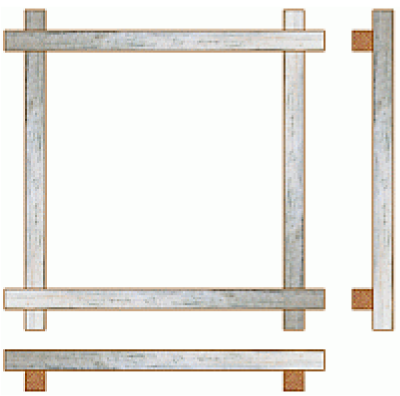
The half-shells lie relatively neatly on cradles but cannot be held securely in position by the steel strap lashing spanning them crosswise. The wooden bracing between the two stacks of half-shells was no doubt put in place with good intentions, but will not hold under likely shipping stresses.



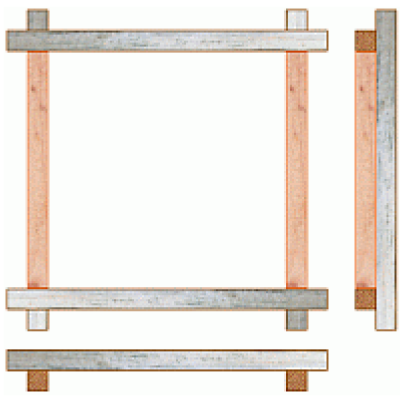
Adequate securing of the half-shells on the flatrack

The easiest securing option is to fit symmetrical direct lashing using claws which engage in the shell stack from above.

The cradle takes the form of a simple cross-bed, the top layer of which consists of squared lumber providing an edge of uniform height which allows the half-shells to be positioned in form-fitting manner thereon.



Simple cross-bed



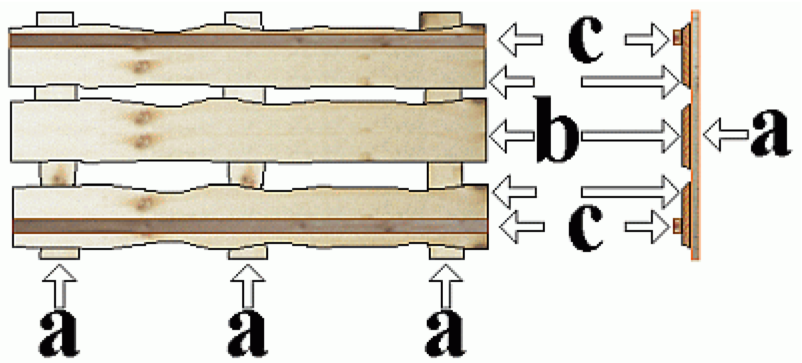
Simple cross-bed, lined

(in each case in plan view and with corresponding side views)

If dimensions allow, half-height open-top containers are suitable for transporting such goods:

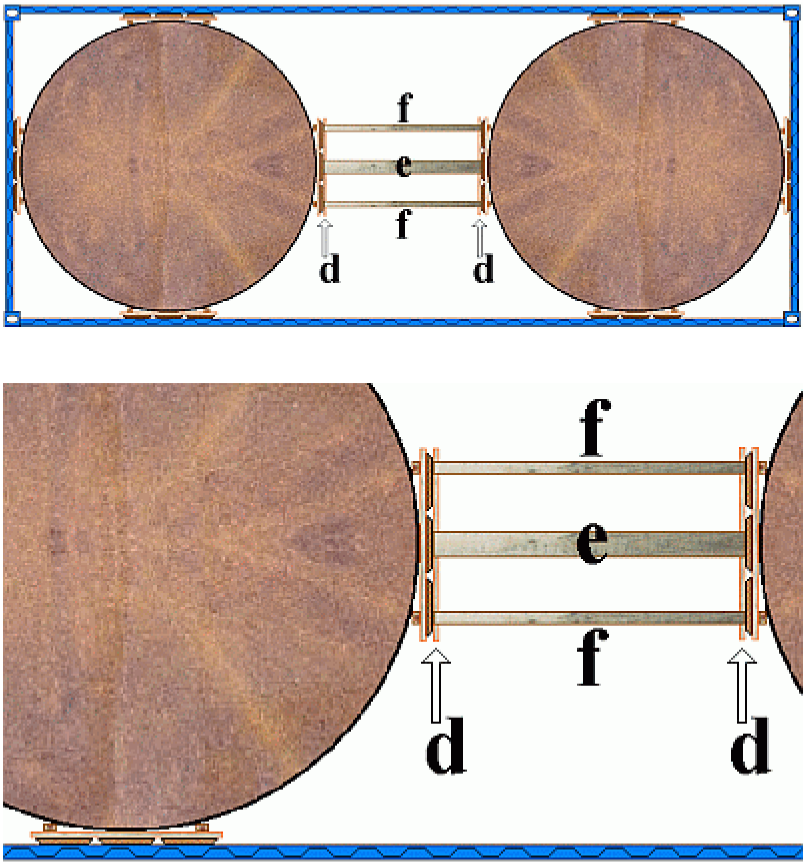
Partial view of a half-height open-top container

The effort involved in securing is kept within limits, since compact stowage can be achieved using simple wooden lattices and bracing. Reasonably priced, unsquared wooden dunnage and laths can be used to secure the cargo to the solid sides of the container.



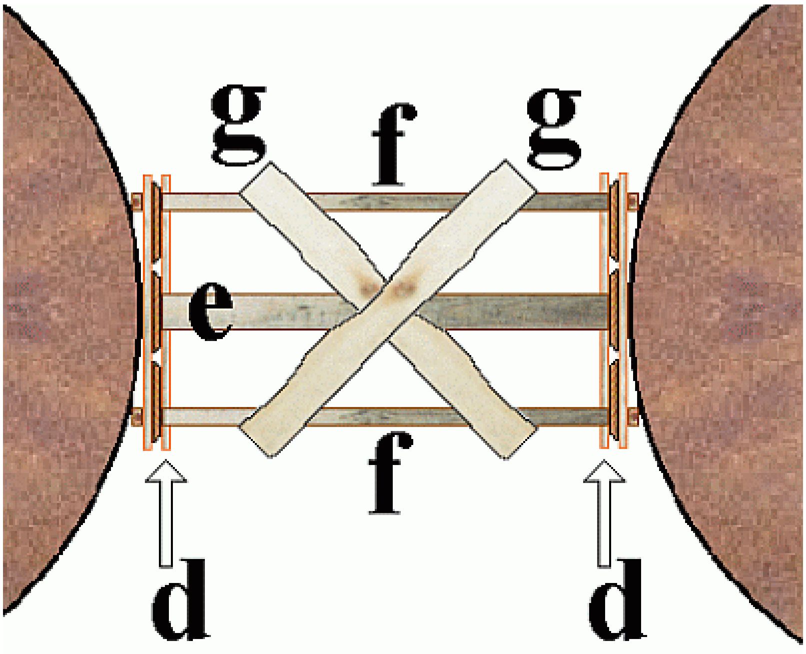
Preparation of reasonably priced securing lumber

The boards (a) and (b) are nailed to one another crosswise. The laths (c) are attached parallel to the outer boards (b). The overall thickness of the boards must match the size of the gaps between half-shells and container side. If the gaps are relatively large, planks may be used instead of the boards or the boards can be adjusted to fit the gaps with additional squared lumber.



Top and selective enlargement below:
Securing of half-shells in a "half-height open-top container"

Bracing is placed in the gap between the stacks of half-shells. Lengthwise wooden members (e) are used on crosswise nailed boards or laths (d) as bracing. These members cannot become laterally dislodged; however, if it is felt that there is a risk of their doing so, additional laths (f) or boards should be fitted, which are arranged as X-bracing, as shown in the detailed view below.



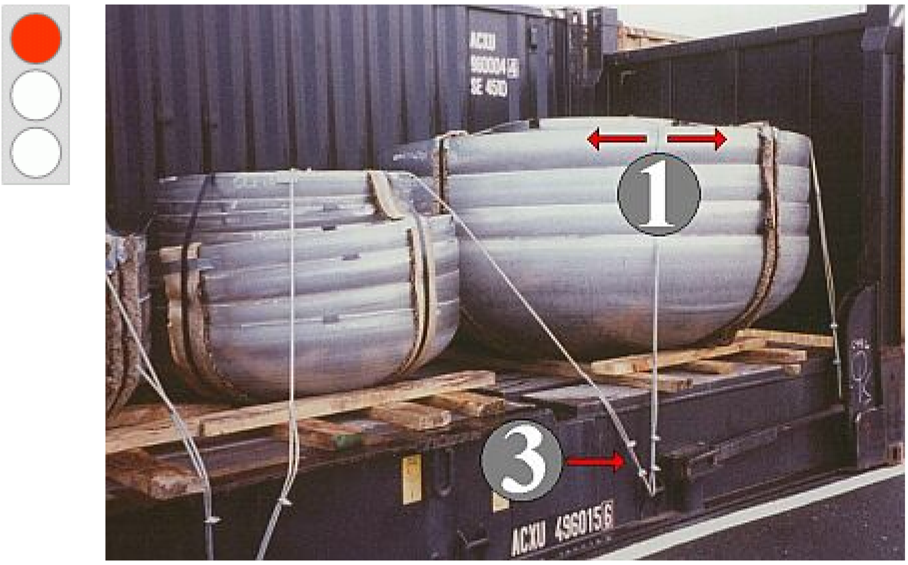
Detailed view of wooden bracing and X-bracing (g)

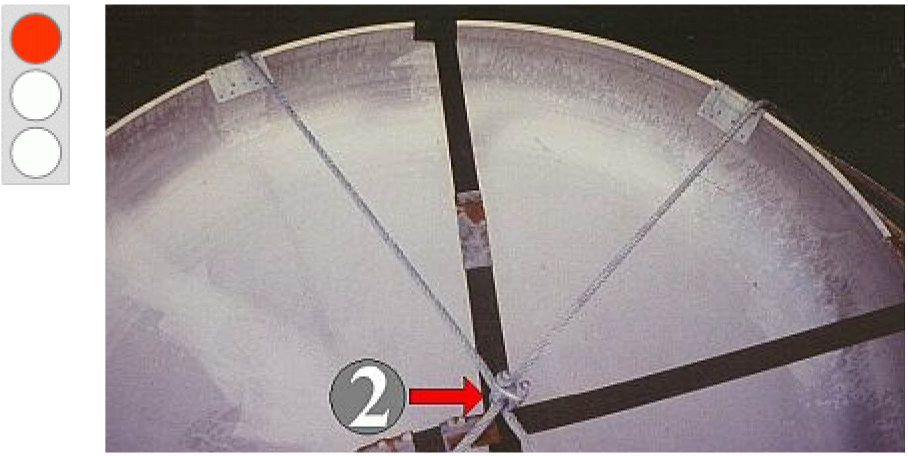
Half-shells on a 40' flatrack

The following example is a good illustration of the errors which can be made when loading such goods.

Inadequately secured half-shells on a 40' flatrack

These half-shells are secured nonuniformly with 16 mm diameter steel wire ropes. They are fitted in such a way that a lasting securing action cannot be guaranteed.

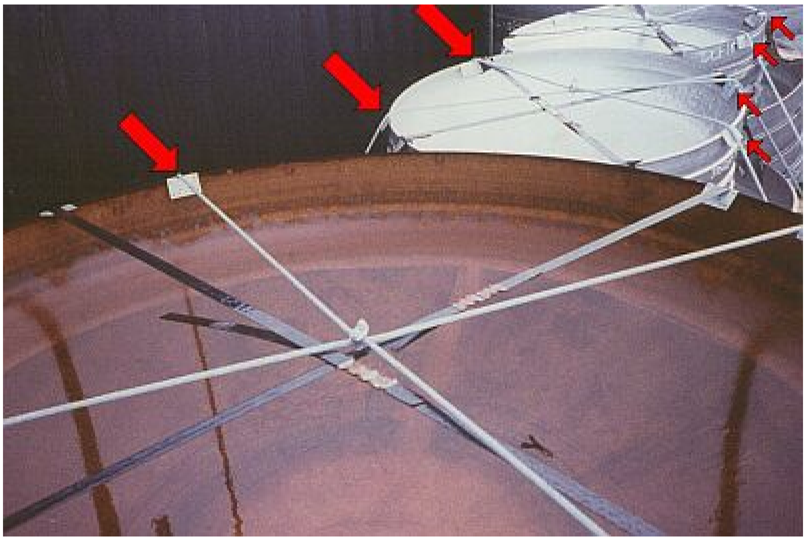




Inadequately fixed half-shells

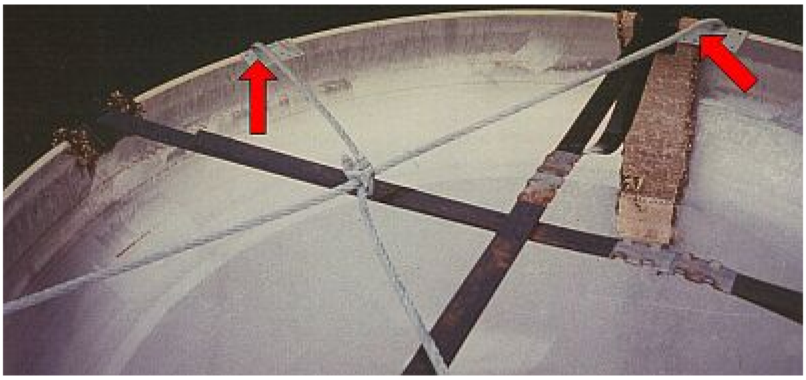
Even slight lateral shifting of the steel wire ropes (1) can slacken the securing means. Fastening the ropes with only two wire clips (3) represents considerable wastage of material, due to the nonuniformity of the maximum securing loads. Moreover, most of the wire clips throughout the flatrack cargo are incorrectly positioned or inadequately tightened.

Displacement of the wire rope cannot be prevented by the wire clip (2) positioned at the point of intersection.



Reduction in strength due to sharp edges

The nonuniformity of the lashing is also caused by using inadequate edge protection. The sharpness of the half-shell edges weakens the steel wire ropes at the deflection points.



The "gentle curves" in the cables
are evidence of inadequate pretension

In addition, the steel wire ropes are inadequately pretensioned. The gentle rounding at the deflection points is clearly visible. Sufficient pretensioning is particularly essential with the selected method of tie-down lashing.

The particular properties of steel wire ropes would in any case lead one to expect that the lashings will slacken in transit;
the reader is referred to the specific comments made in the section headed Lashing materials.

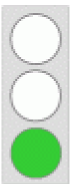
Possible securing with claws

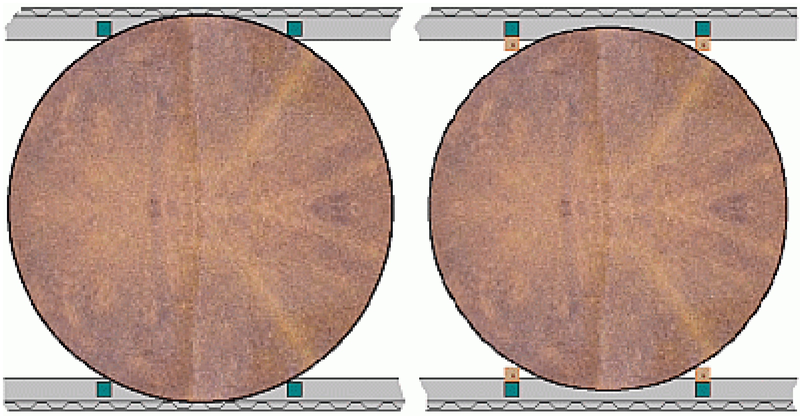
Adequate securing of these half-shells on this flatrack could also be achieved by using claws, which are used as direct lashings and with which a completely tight fit is achieved.

The most cost-effective cargo securing option is to provide containers suitable for transporting half-shells. In the above case, recourse should have been made to flatracks with insertable stanchions.

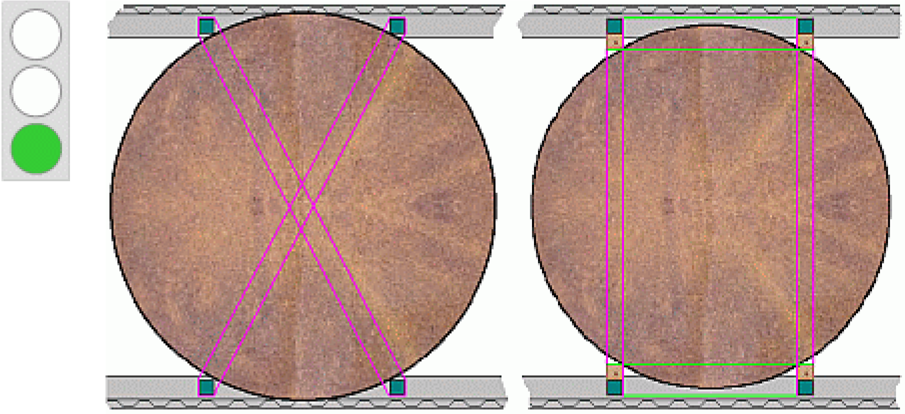
Simple, quick, reasonably priced securing options are available, depending on the diameter of the half-shells: either the half-shells are positioned directly between two pairs of stanchions inserted parallel to the sides or the stanchions are modified beforehand by squared lumber fixed to the insides thereof in such a way that the half-shells can be fitted precisely between the four stanchions. Small stowage gaps can additionally be filled with board ends or the like.

To increase the strength of the stanchions and at the same time to provide the half-shells with a really tight-fitting "stanchion corset", crosswise lashing is provided between the "plain" stanchions and rectangular lashing is provided between the stanchions lined on the inside.



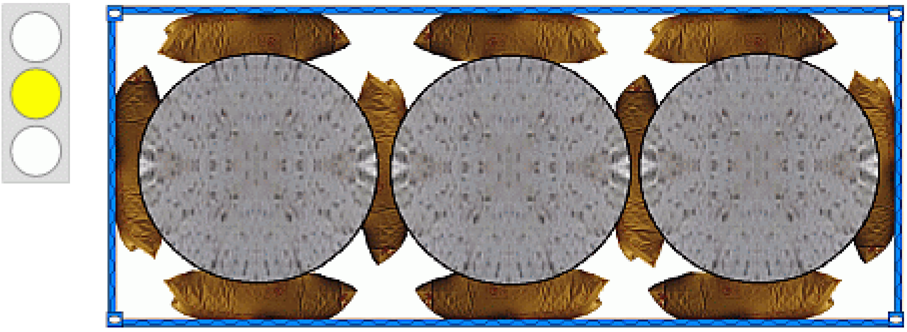


Ideal securing conditions using flatracks with insertable stanchions



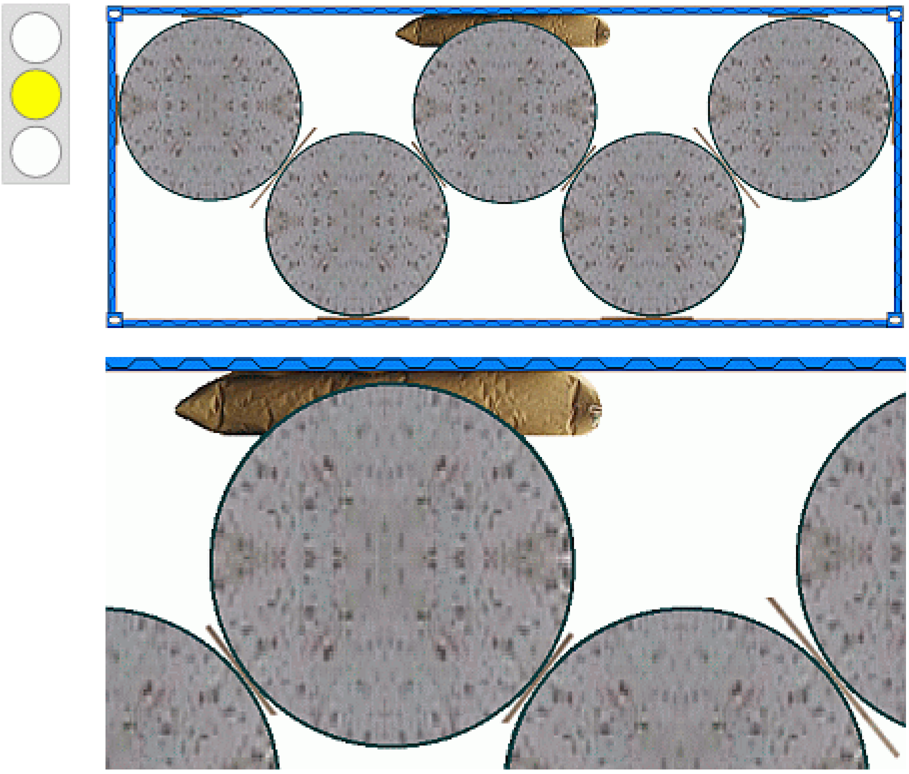
Crosswise and rectangular lashing of stanchions

It would be worth checking whether it is possible to stow certain half-shells in half-height open-top containers and secure them with airbags. The following Figure is just a suggestion. The airbags must fit firmly. No sharp edges should be present; if the edges are sharp, they must be appropriately padded so that the airbags are not damaged.



Possible use of airbags for securing

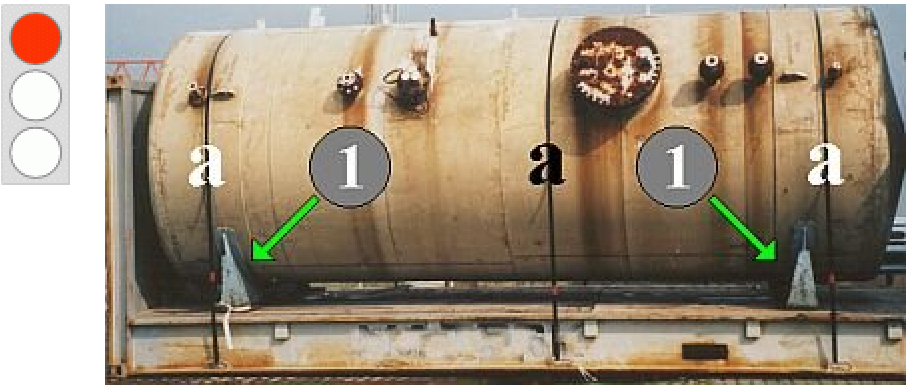
Consideration should also be given to whether a combination of plywood sheets, boards and the like with airbags can provide adequate securing. This method would certainly be cheap.



Top and selective enlargement below:
Combination of plywood sheets and airbags for securing

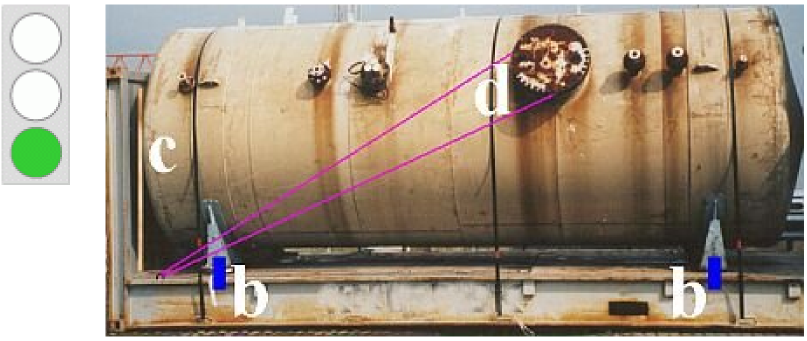
5.2.1.7 Boilers and tanks on flatracks

Used plant part on a 40' flatrack



Inadequately secured boiler on a 40' flatrack

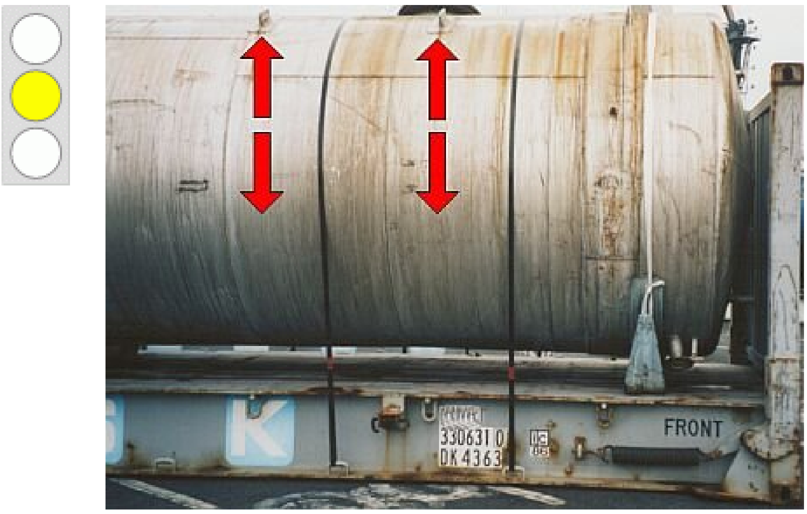
The steel cradles (1) have enormous potential for providing safe securing. However, they do not provide adequate cargo securing when used in combination with these three steel strapping tie-down lashings.



Adequately secured boiler

Full lateral securing can be achieved by welding to the cradles angles and/or guide plates (b) which engage over the edge of the flatrack.

For lengthwise securing in the one direction, the boiler is packed tight against the front end wall and/or any small gaps are filled with lumber (c).
To prevent movement to the other end wall, a lashing is guided obliquely relative to the direction of movement on each side (d). The tie-down lashings then assume the function of direct securing in the vertical direction. If a material with good recovery were positioned between the steel strapping tie-down lashings and the boiler, the tie-down lashings could produce additional securing forces in all horizontal directions due to their pretension. The numerical value of these securing forces would be even greater if friction-enhancing material were laid or had been laid between the steel cradle and the flatrack floor.



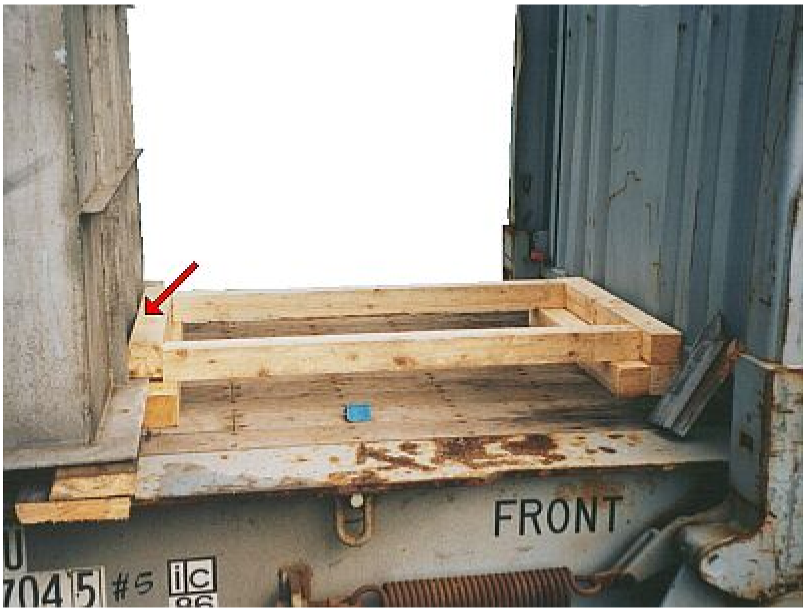
Alternative securing options

It should have been checked whether direct lashings would have met the securing objectives better than the tie-down lashings.

Used plant parts on a 40' flatrack

Inadequately secured plant parts on a 40' flatrack

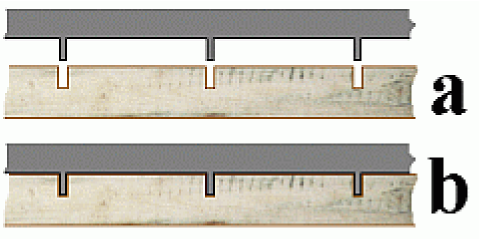
Neither the left-hand, boiler-like plant part nor the right-hand receptacle is properly secured:



Deficiencies in the wooden bracing against the front end wall

The crosspiece lying against the item of cargo is too short and has an effective cross-sectional area of only a few square centimeters. The gaps between the item of cargo and the crosspiece need to be filled.

However, it is better and quicker to cut slits in an additional crosspiece with a saw (a), so that the metal webs on the receptacle can lie flush against the lumber (b).



Options for eliminating deficiencies

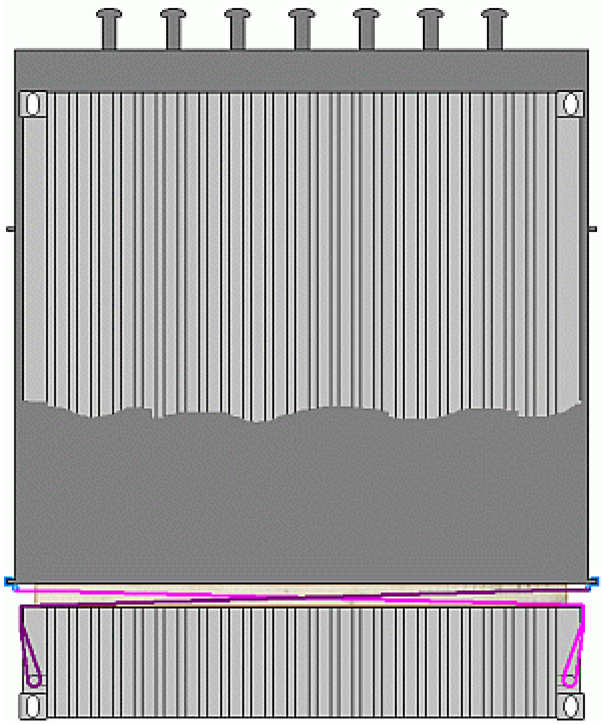
Deficiencies in the wooden bracing between the items of cargo

The wooden bracing between the items of cargo exhibits the same shortcomings as that against the front end wall.

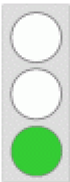
The bracing lying against the right-hand receptacle can be modified as described above. Against the left-hand receptacle, the upper crosspiece must be long enough to cover the boiler edge.

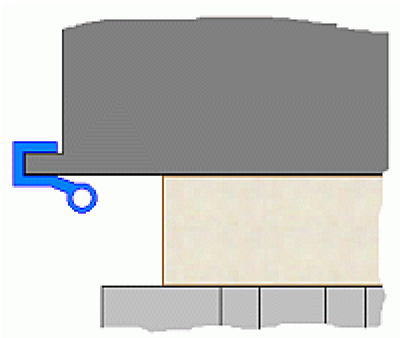
Inadequate securing of the receptacle

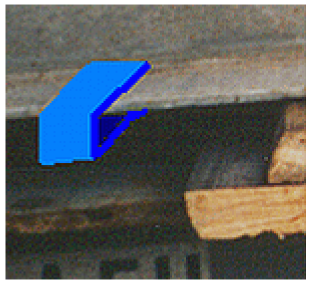
The lateral securing of the receptacle itself is inadequate, consisting as it does of only three tie-down lashings.



Lateral securing by direct lashings using claws



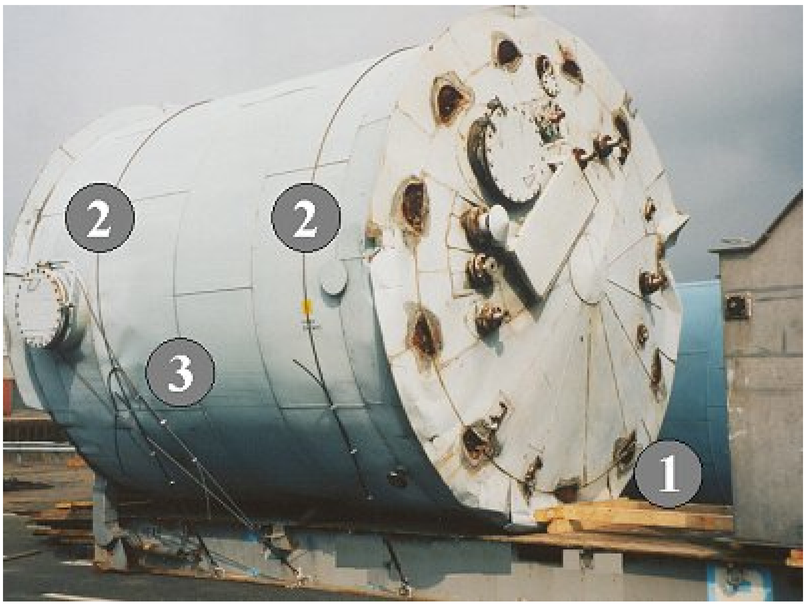




Use of claws for lateral securing - detail

A good way of providing lateral securing is to use claws, which can be applied to the base profiles of the receptacle.

The tie-down lashings are retained to provide vertical securing and to secure against tipping.



Inadequate securing of a used plant part

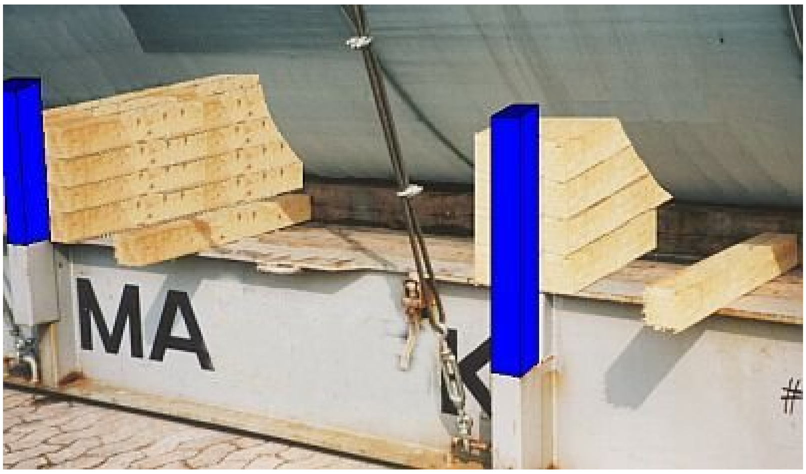
The wooden bracing (1) between the two items of cargo has already been criticized. The lashings (2) act solely as tie-down lashings due to friction forces and as direct lashing against upwards motion. They cannot provide additional lateral securing because of the overwidth. Although the direct lashing (3) could hold the boiler to a degree in the lateral direction, a longitudinal component also acts in the direction of the bracing. The wire lashings do not comply with the instructions given above, being nonuniform.

Inadequate lateral securing in the base area

On this side, only one beam is positioned lengthwise in the base area and attached with nails.

Inadequate lateral securing with wooden fixings

On the other side, two wooden fixings (5) are positioned crosswise in addition to the laterally fitted squared lumber (4) and are fixed with a few nails.

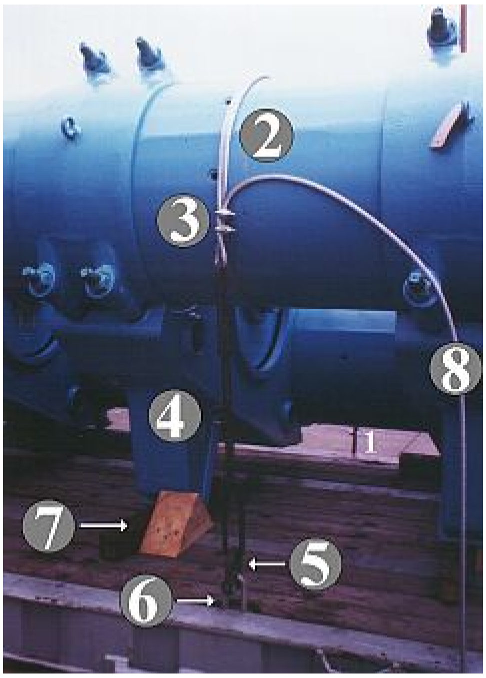


Improvements to lateral securing

The stanchion pockets provided allow adequate lateral securing of the boiler with wooden members and relatively short case profiles or steel beam ends. For this to be feasible, however, the boiler walls have to be able to withstand this load. If they can, then the tie-down lashings once again seem sensible and no space is left for the direct lashing (3) to the flange shown in the third last picture - under these new conditions, it may be dispensed with.

Plant part on 40' flatrack

Above and right: inadequately secured plant part on a 40' flatrack



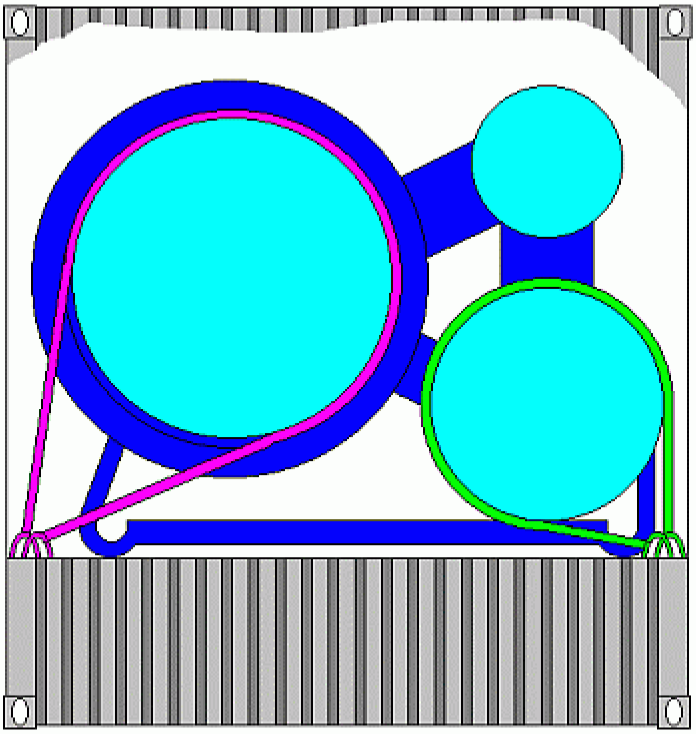
In the arrangement shown, the plant part was secured by three lashings. A 16 mm diameter steel cable was attached to a lashing bar (1) on the one side of the flatrack with one correctly applied (a) and one incorrectly applied wire clip (b). From there, the cable was passed round the component (2) with a round turn, i.e. an additional winding, and attached to one end of a turnbuckle (4) with two incorrectly applied wire clips (3). The other end of the turnbuckle was attached by a shackle (5) to the lashing point (6) recessed into the floor of the flatrack. In addition, the shipping package was fixed in the floor area of the flatrack by three nailed-down wedges (7) on each side. The wedges were all incorrectly cut.

The wire lashings were nonuniform for various reasons. The lashing point at (1) has a maximum securing load of approx. 7,500 daN, while that of the lashing point at (3) recessed into the flatrack floor is only approx. 4,000 daN. The steel cable itself has a maximum securing load of something over 10,000 daN, but only 5,000 daN at most are utilizable if, as is the case here, only two wire clips are applied in each case. The perceptible pretension at the turnbuckle (4) was very high. However, because of the round turn, not very much of this was applied to the lashing point (1), which is clear from the round shape of the wire loop at (c). Added to this waste of resources due to nonuniformity is the loose end of the wire (8), which was more than 2 meters long and signifies additional waste of material.

It must be pointed out that this flatrack had six integral lashing belts each with maximum securing loads of 2,000 daN guided over lashing reels, albeit on one side.

Incorrectly cut wedge

Since the wedge has been incorrectly cut or used, the nails have been knocked into the end grain. Even here at the point of departure it is clear that the wedge is splitting and the same could be said for all the other wedges.



Effective lateral and vertical securing by loop lashings

Loop lashings, with their ends applied to separate lashing points, would have allowed adequate transverse and vertical securing. Full lengthwise securing would have been readily possible if the end feet had been braced against the end walls of the flatrack. The most sensible option economically would be to use the lashing belts of the integral lashing reels on the one side as loop lashing and to secure the other side with prefabricated lashing belts, which must have an identical maximum securing load.

5.2.1.8 Concrete pump on a flatrack


Inadequately secured concrete pump

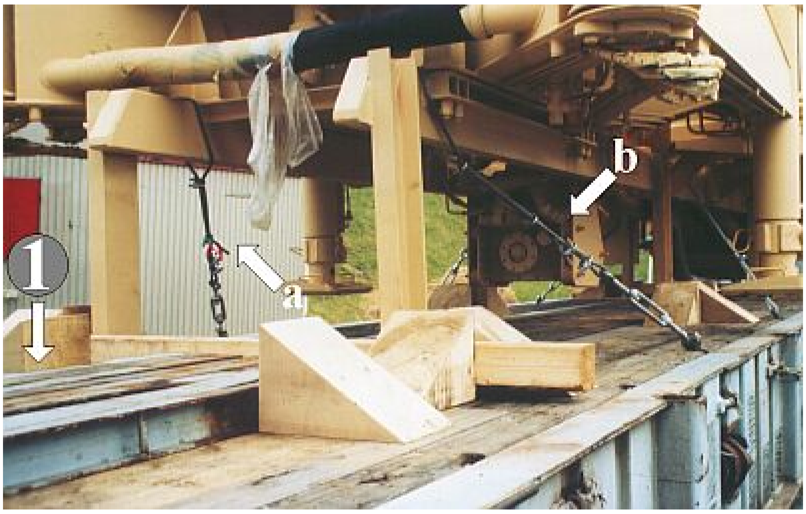
Considerable effort has been made to secure this concrete pump. However, the securing action achieved thereby is minimal because of the nonuniformity of the wire rope lashings used. It is incomprehensible why the lashing reels incorporated into the flatrack have not been used.


Securing material wastage

The wedges used have been incorrectly cut and their efficacy is minimal. They weren't basically even necessary. The wire rope lashings are nonuniform and only some of the possible maximum securing load has been achieved.

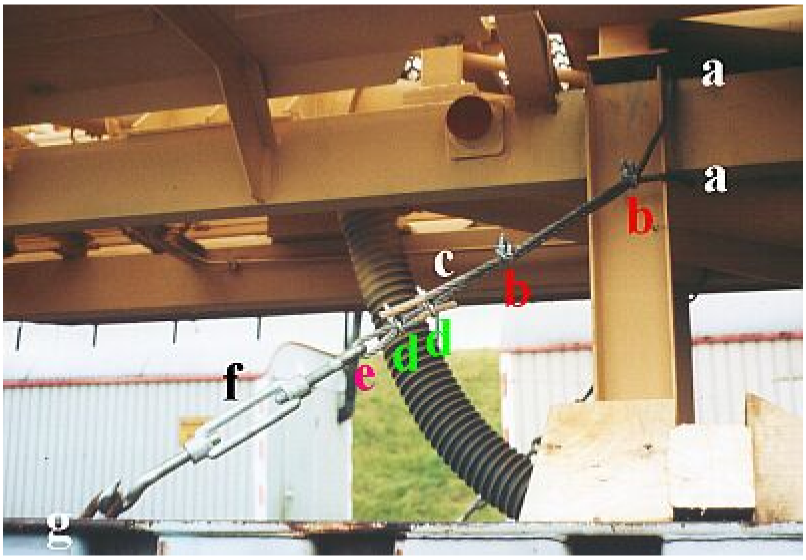
The use of tie-down lashings is particularly ridiculous, since the frame of the concrete pump can move freely sideways in them:


Tie-down lashing over the frame parts of the concrete pump



Material wastage due to pointless, nonuniform securing

Securing of the stanchions of the flatrack is unnecessary, since the flat has stanchion pockets at the side in which the stanchions can be inserted when not in use. None of the wire rope lashings applied are uniform. This will be explained with reference to the two lashings (a) and (b).



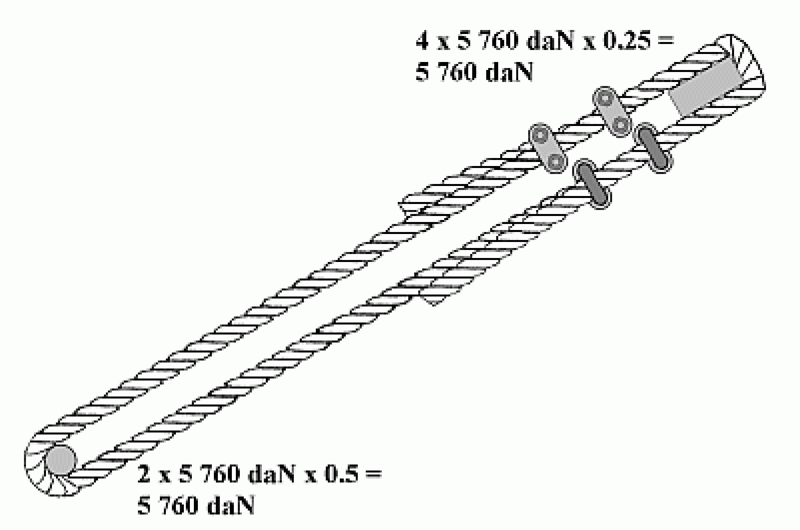
Nonuniform wire rope lashing

A 12 mm diameter steel wire rope was used with a maximum securing load of 5,760 daN per single run. The following are the values for the maximum securing load of the individual components of the lashing or at the various points of the lashing:

a	As a result of deflection around sharp edges, load can be calculated as 2 times working parts each of 5,760 daN x 0.25 =	~ 2,880 daN
b	Two wire clips have been positioned with the bow on the working part. In addition, they have clearly not been tightened enough, meaning that the strength of the connection cannot be calculated. At any event, it is less than 2,880 daN.	< 2,880 daN
c	Loose or non-working part. This is where the shackles should have been placed.	
d	These two wire clips have been correctly positioned and tightened more firmly. If the correct tightening moment has been achieved, a strength is obtained in conjunction with the curvature of e of 2 parts each of 5,760 daN x 0.5 =	~ 5,760 N
e	Diameter of curvature corresponds to cable diameter	
f	Maximum securing load of turnbuckle approx.	~ 4,000 daN
g	Maximum securing load lashing point approx.	~ 4,000 daN

With virtually the same length of wire and the same number of wire clips, but a different way of proceeding, the following values could have been achieved:

At point of connection
to frame:
5,760 daN



At point of connection
to turnbuckle:
5,760 daN

The weak points in this variant are the lashing ring recessed into the flatrack floor and the turnbuckle with a maximum securing load in each case of 4,000 daN.

If the lashing bars fitted to the side of the flatrack with a maximum securing load of approx. 6,000 daN are used, the maximum securing load of a lashing may be increased. Compared with the maximum securing load of less than 2,880 daN which was originally achieved...

The maximum securing load of this lashing amounts to less than approx. 2,880 daN.

.... 5,760 daN maximum securing load may then be achieved per lashing.

The maximum securing load of this lashing amounts to 5,760 daN

Since the forces are distributed to the working parts, even a turnbuckle of only approx. 3,000 daN could be used.

The concrete pump could easily have been secured to the flatrack with a total of four lashings, see below:

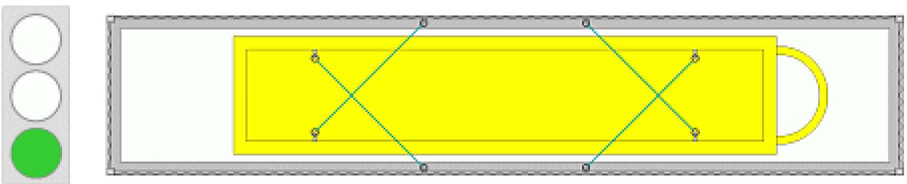


Diagram showing the principle of adequate securing with four direct lashings

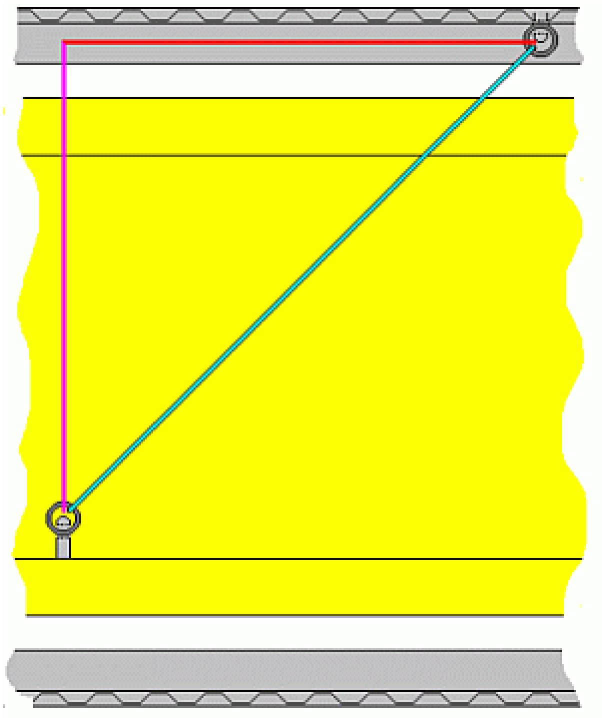


Diagram showing the principle of lashing and the horizontal components

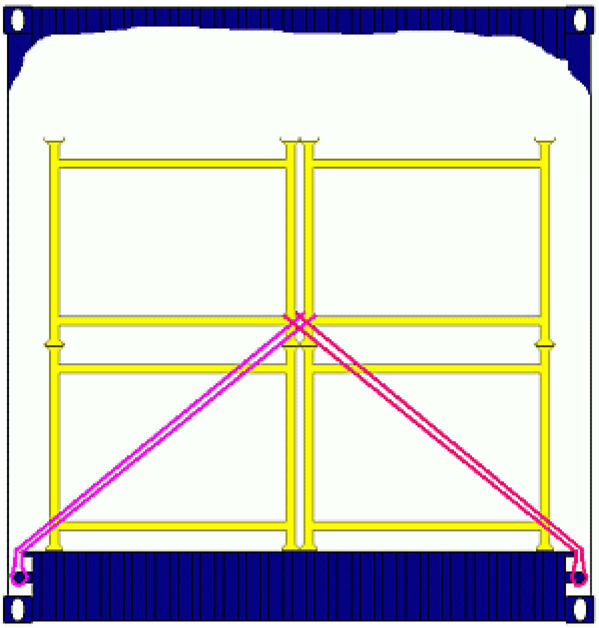
The longitudinal and transverse components are identical. The vertical components are somewhat smaller per lashing. However, since all the lashings have this vertical component, wholly satisfactory securing is achieved.

5.2.1.9 Axles on flatracks

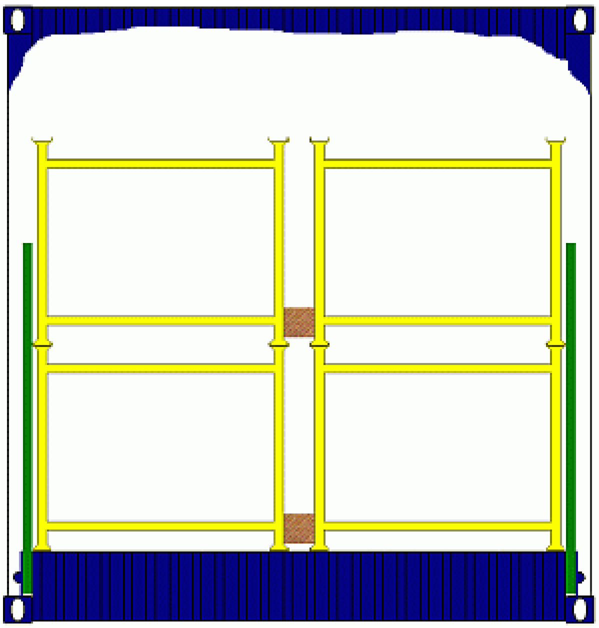
Example: Truck axles on a 40' flatrack

Unsuitable securing of truck axles on a 40' flatrack

Producer and trader have designed special stands for transporting axles and had them manufactured. The axles are packed into the stands with a tight fit. It is incomprehensible why the stands have been secured on the flatrack with tie-down lashings. The cargo can move freely under the tie-down lashings.. Only with a tight fit can the forces arising during transport be absorbed. To this end, the flatrack stanchions should be used and/or securing with oblique lashings to the sides.



Tight-fit securing of the stands using oblique lashings



Tight-fit securing using stanchions and centrally positioned squared lumber

It goes without saying that combined methods and other types of securing are also feasible.

5.2.2 Bales in box containers

As a homogeneous cargo, bales are relatively easy to pack and secure. In each individual case, how the bales should be packed depends on the dimensions and proportions of the bales. Also of importance for operating procedures is whether forklift trucks without add-ons or with bale clamps can be used, since this determines whether, for example, floor and interlayer dunnage of wooden boards or thick battens must be laid so that the bales can be handled with normal forks.

The strength of the bales and the way in which they are strapped or wrapped is also relevant to handling. Some bales, e.g. those consisting of combed top, are very sensitive and require particularly careful operating procedures.

Purely manual stowage is impossible because the individual bales are so heavy. An exception could be made if hard-top open-top containers are used, since these allow the bales to be directly set down using lifting gear with wool hooks or similar load suspension devices, individual bales then having merely to be straightened. Manual stacking is out of the question.

As a rule, standard box containers are used. The stowage factors mean that really only 20' containers can be used - 40' containers could only be used for relatively loosely compressed bales of light materials.

Bales requiring stowage consist in particular of sheep's wool, cotton and tobacco of widely varying origin, combed top, textiles, cellulose, paper, aluminum residues, waste paper etc. Many natural fibers, such as sisal etc, which used to be transported (carried) in bales, are now more and more frequently shipped in further-processed forms, such as "hanks", reels etc. Natural rubber, empty bags (gunnies) and similar products are still transported in bales, however.

Bales, standing lengthwise, without dunnage

Bales, standing lengthwise, with dunnage

The bales are packed standing, with their narrow, rounded sides in the lengthwise direction. Wooden dunnage is not required if the bales are handled with bale clamps. The advantage is that no additional moisture is introduced into the container and sensitive bales do not suffer pressure damage.

If wooden dunnage is laid, it should be kiln dry or at least dry. If the moisture content is not known, the lumber should be covered with strips of material which can neither damage the bales nor allow moisture to pass through. In the example, the lumber is laid in such a way that the bales can be picked up in pairs by the forklift truck. To simplify packing and stripping operations, the bales can be tied together in pairs with binder twine. If there is a risk of pressure damage, wooden dunnage must not be laid or it must be laid sufficient densely to prevent pressure damage while still leaving sufficient gaps for forks to pass between it.

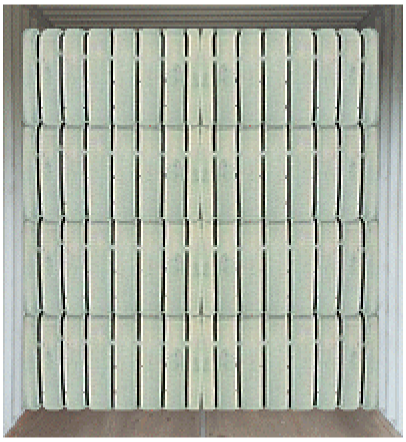
Bales, standing crosswise, without dunnage

Bales, standing crosswise, with dunnage

Here the bales were packed standing, but with their rounded sides in the transverse direction. The wooden dunnage was laid in such a way that the bales can be picked up individually and the forks can be positioned close to the bale edges.

3 layers of bales lying horizontally, without dunnage

3 layers of bales lying horizontally, with dunnage



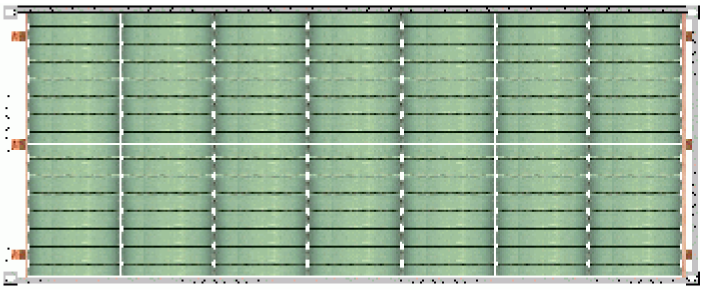
4 layers of bales lying horizontally, without dunnage

4 layers of bales lying horizontally, with dunnage

Large tobacco bales, without dunnage

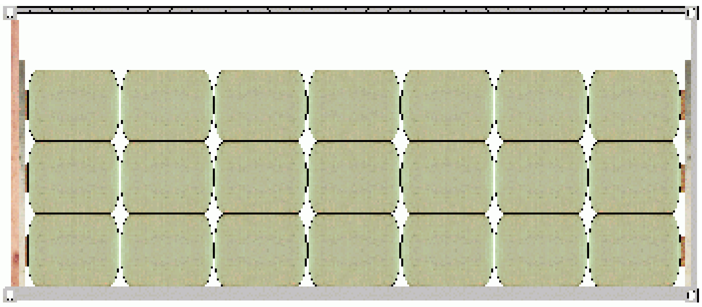
Small tobacco bales with interlayer dunnage

Tobacco bales are very sensitive to pressure damage and must be stowed flat. Special measures with regard to air circulation etc. are described under Basic stowage methods.



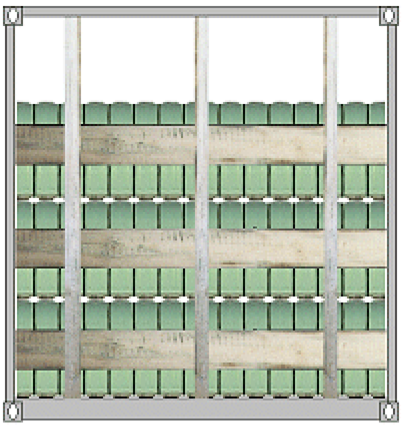
Bales in a 20' container (plan view)

Because the bales are so dimensioned that they occupy the full width of the container, the gap at the front end wall of the container is filled with a wooden lattice. A lattice of similar construction, but with additional squared lumber, is positioned on the door side.



Bales in a 20' container (side view from right)

The smooth tops of the bales point towards the outer walls of the container. If contact with the container walls was likely to cause degradation in quality, appropriate measures would have to be taken.



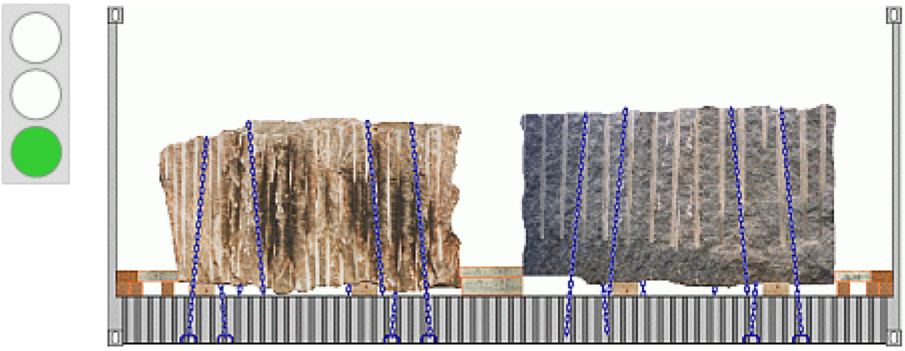
The horizontal boards of the lattice should be positioned in such a way that the bales are held exactly centrally, and their width should be such that on the one hand there is no risk of pressure damage and on the other hand they retain sufficient strength. The squared lumber uprights may be braced against the door frame. This may be achieved by gentle bracing or by using tapered blocks.

Bales in a 20' container (view from door end)

5.2.3 Blocks, slabs etc.

5.2.3.1 Granite blocks on flatracks

It is very easy to stow and secure granite blocks on flatracks Since chains are best for "heavyweights", chains and loop lashings should be used for lateral securing. Squared lumber bracing is suitable for lengthwise securing.



Securing of granite blocks on flatracks

The number and size of the wooden bracing members may be readily determined using the rules of thumb already given.

5.2.3.2 Granite curbstones in box containers

When packed in box containers, granite counts as a "heavy" cargo, since its stowage factor is such that the container's volume cannot be fully utilized. Depending on volume and payload, the volume-to-payload ratio of 20' containers ranges from approx. 1.2 - 1.8 m³/t. The stowage factor of granite is around 0.36 m³/t, i.e. a container can only be filled with such cargoes to between a fifth and a third of its volumetric capacity. Depending on the unitization of the granite articles, their shape and any wooden props or wooden interlayers used, this value may increase to approximately half the container volume.

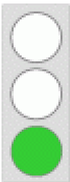
Compactly stowed granite bundles

The granite is bundled on squared lumber underlays using high-strength steel wire. The wires themselves are guided through holes drilled in the ends of the squared lumber. The bundling and packing method used favors the use of forklift trucks and load transfer to the container floor. Since the tied-on wooden underlays lie lengthwise, the admissible line load cannot be exceeded. The load is thus well distributed over the bottom cross members of the container. Small stowage gaps can be filled with lumber.

Granite bundles - gaps filled with airbags and lumber

If the ends are sharp, boards or wooden sheets should be inserted between the container wall and the granite. The same applies if airbags are inserted at sharp-edged ends, but is unnecessary in the case of straight hewn granite. Gaps to be braced with airbags should not be much larger than approx. 20 cm. To achieve uniform weight distribution, the stone packages should be packed alternately in groups. A group should correspond approximately to the length of an airbag. It must be ensured that the airbags cannot slip out in an upwards direction,

a problem which can be prevented by using boards and/or wooden sheets to produce inverted "funnels" which are open wider at the bottom:

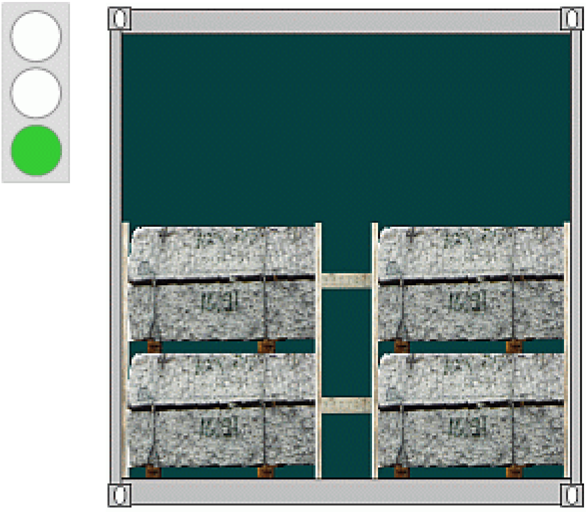


Granite bundles - gaps filled with airbags and lumber

Unfavorable packing method

Such a packing method is not advisable. The container floor is loaded unfavorably, since the tied on wooden underlays extend parallel to the bottom cross members of the container. Forklift trucks can only be used at right angles to the underlaid lumber. Since the bundling was not intended for this, however, considerable damage may occur during packing and unpacking. Damage to the bundles is inevitable. Such packing would theoretically be possible if additional wooden supports and interlayers were used. However, if the container is carried lengthwise (fore and aft stowage), even the smallest of gaps would be sufficient for the rolling motion of the ship to deform the bundles.

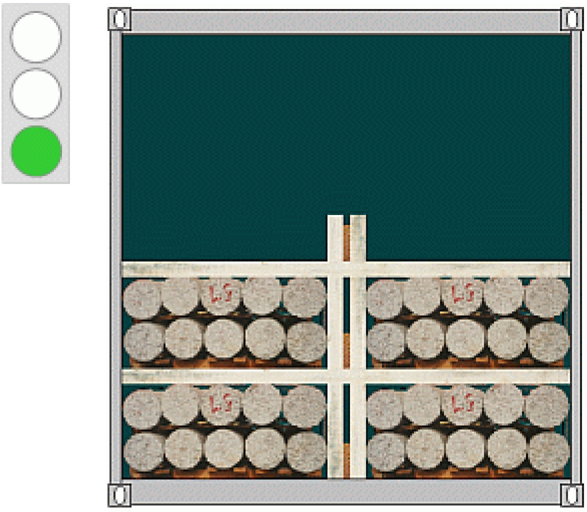
The curbstones shown are around a meter in length, making the following packing pattern easily achievable:



Granite curbstone bundles: gaps braced with boards and squared lumber

The bundles are packed to the left and right against the side walls using upright wooden dunnage. The "aisle" left in the middle is secured with wooden bracing consisting of boards and squared lumber. The squared lumber is positioned at the level of the respective "seams".

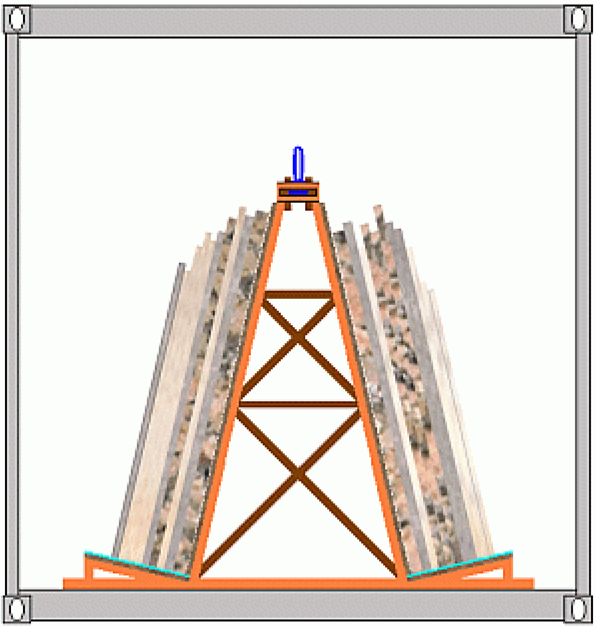
5.2.3.3 Granite columns in box containers



Granite column bundles: gaps braced with squared lumber

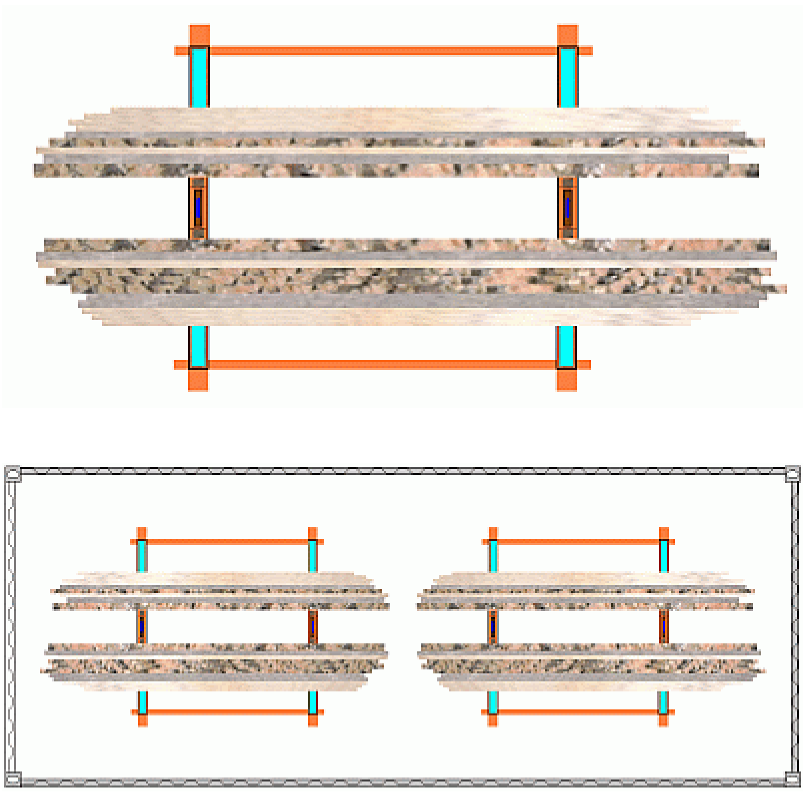
Intermediate and top wooden members positioned crosswise simplify bracing of the central gap. The vertical upright blocking is attached to them. Final strength is achieved by boards or beams inserted longitudinally, which guarantee overall compact stowage.

5.2.3.4 Granite and marble slabs on A-frames



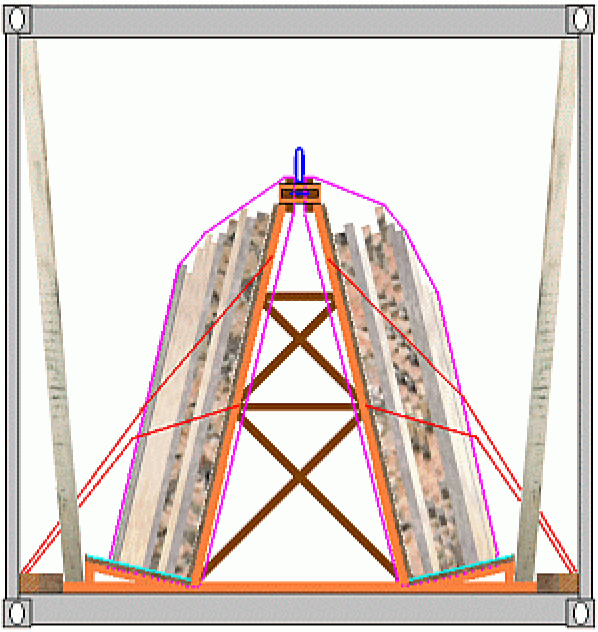
Granite slabs on a steel A-frame suitable for use with lifting gear and forklifts

In the event of regular outward-and-return transport, it is worth building permanent frames for transporting granite, marble and slate slabs and other similar slab-like material which are suitable for use with lifting gear and forklift trucks.



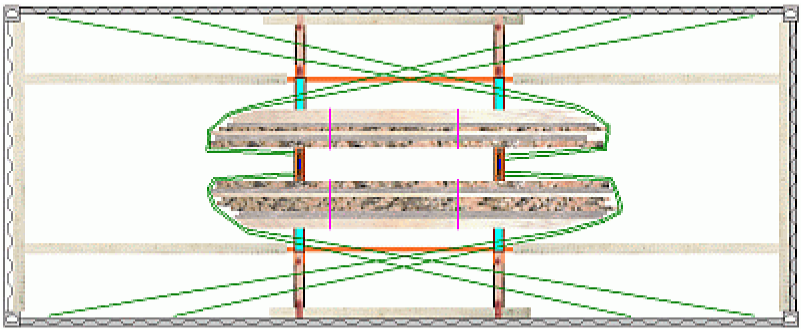
Granite slabs on steel A-frames - plan view

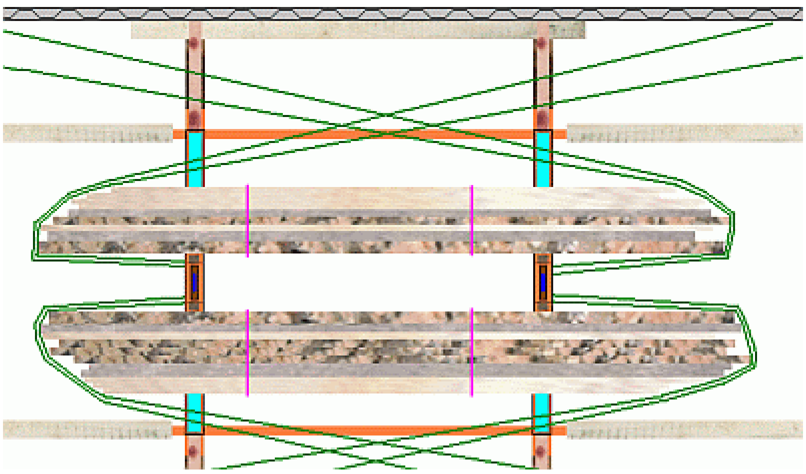
Whether 1 or 2 frames are loaded per container depends on the mass of the cargo. The nature of the frames allows stowage in both standard box containers and open-top containers.



Secured A-frame

The slabs may be secured transversely and vertically to the frames prior to loading. To this end, strapping is tensioned around each slab and frame half. In the container, the frames are secured against lateral and longitudinal shifting with squared lumber. Shoring prevents the frames from moving vertically and tipping. Direct lashing is used to prevent any lengthwise movement of the slabs.



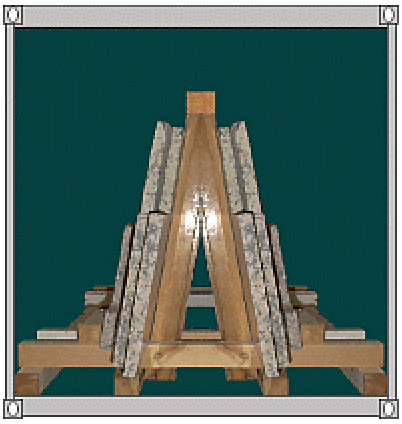


Top and selective enlargement below: Lengthwise securing using direct lashing - plan view

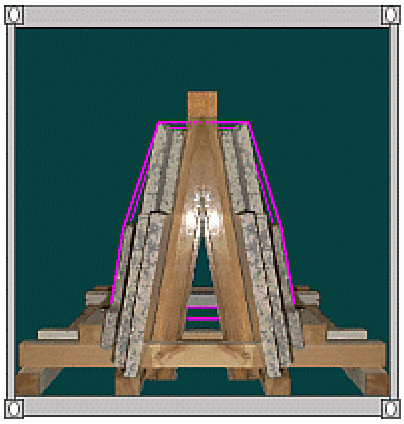
The direct lashings are attached to lashing points at the tops of the A-frames, pass forward round the protruding sections of the slabs and are tightened on the opposite side. Since the slabs are very fragile, the lashings must be only slightly pretensioned. The cross beams of the A-frames which slope obliquely upwards and outwards are covered with friction-enhancing material, so that the majority of the longitudinal forces are eliminated by friction with the floor.

Laterally arranged half frames

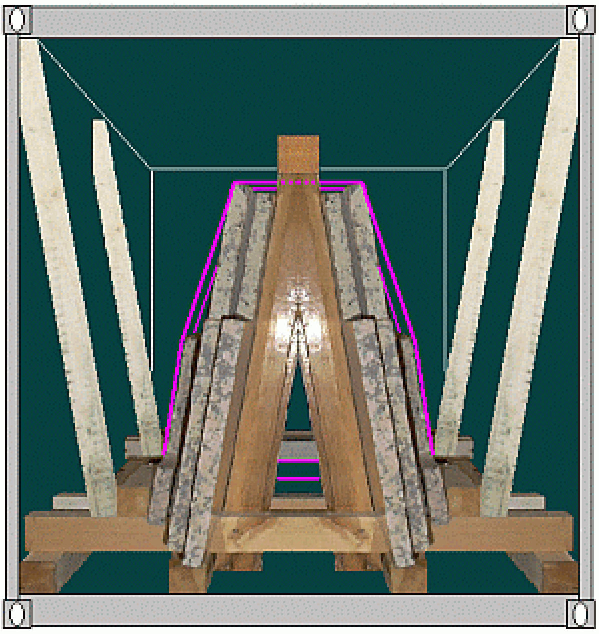
The cost of securing is considerable if such slabs have to be secured using single-use material. For packing in open-top containers it is expedient to build "half frames" on each side, load on the slabs and shore them crosswise. The crosswise squared lumber members are held in each case by two vertical or oblique squared lumber members. Loop lashings are suitable for longitudinal securing and are passed around the tops of the slab sections and pulled taut at the other container end.



Granite slabs on A-frame



Transverse securing with strapping



Securing against vertical and tipping movement using shoring

A-frames made from squared lumber are, of course, also feasible for one-off transport. The arrangement of the wooden members is intended only as a suggestion and must always be tailored to the mass of the cargo, the transport routes etc.

5.2.4 Vehicles and construction machinery

5.2.4.1 Automobiles in standard containers

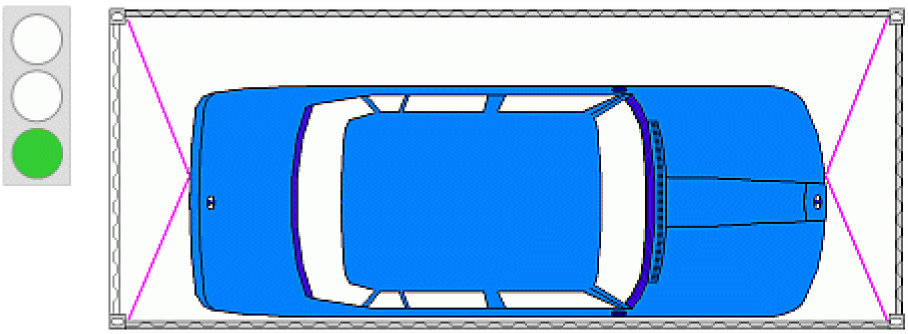
Automobiles in containers

Compared with other cargoes, automobiles are considered a very light container cargo. The mass of an automobile constitutes only a fraction of the payload of the container. The rubber tires are a great advantage with regard to cargo securing, with coefficients of sliding friction ranging from at least μ = 0.4 to μ = 0.8 as a function of the container floor. Even with assumed accelerations of 1 g in the longitudinal and transverse directions, securing forces of only 200 - 600 daN would be necessary per metric ton of cargo mass.

As far as the "fitness for loading of the container" is concerned, particular care needs to be taken to ensure that no sharp-edged or pointed objects have been left in or on the floor which could damage the tires. No materials with a relatively high moisture content, such as lumber etc., should be in the container with the automobile. Condensation could cause mold to appear on upholstery etc. or other damage.

When opening containers packed with road vehicles, it should be ensured that no sparks are produced and that there are no naked flames in the vicinity, as leaking fuel could have created an explosive mixture in the container. Access to such containers should therefore only be permitted after thorough ventilation.

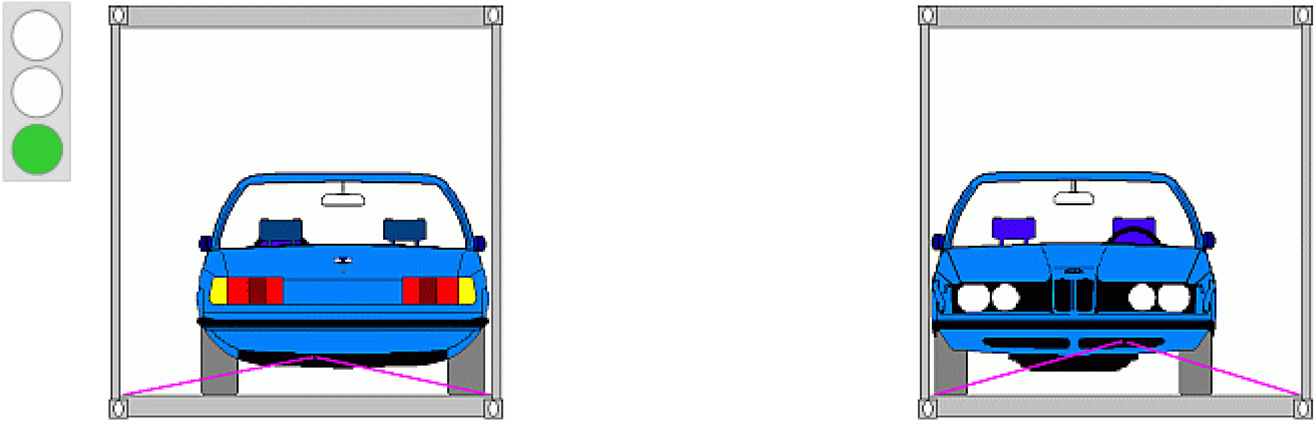
If vehicles are driven directly into containers, space must be left for getting in and out. The vehicles have therefore to be driven up relatively closely against one of the container walls (the right-hand container wall in the case of left-hand drive vehicles). However, enough space must be left to rule out the chance of contact with the container walls even if the vehicle structure sways.



Lashed automobile in a 20' box container - plan view

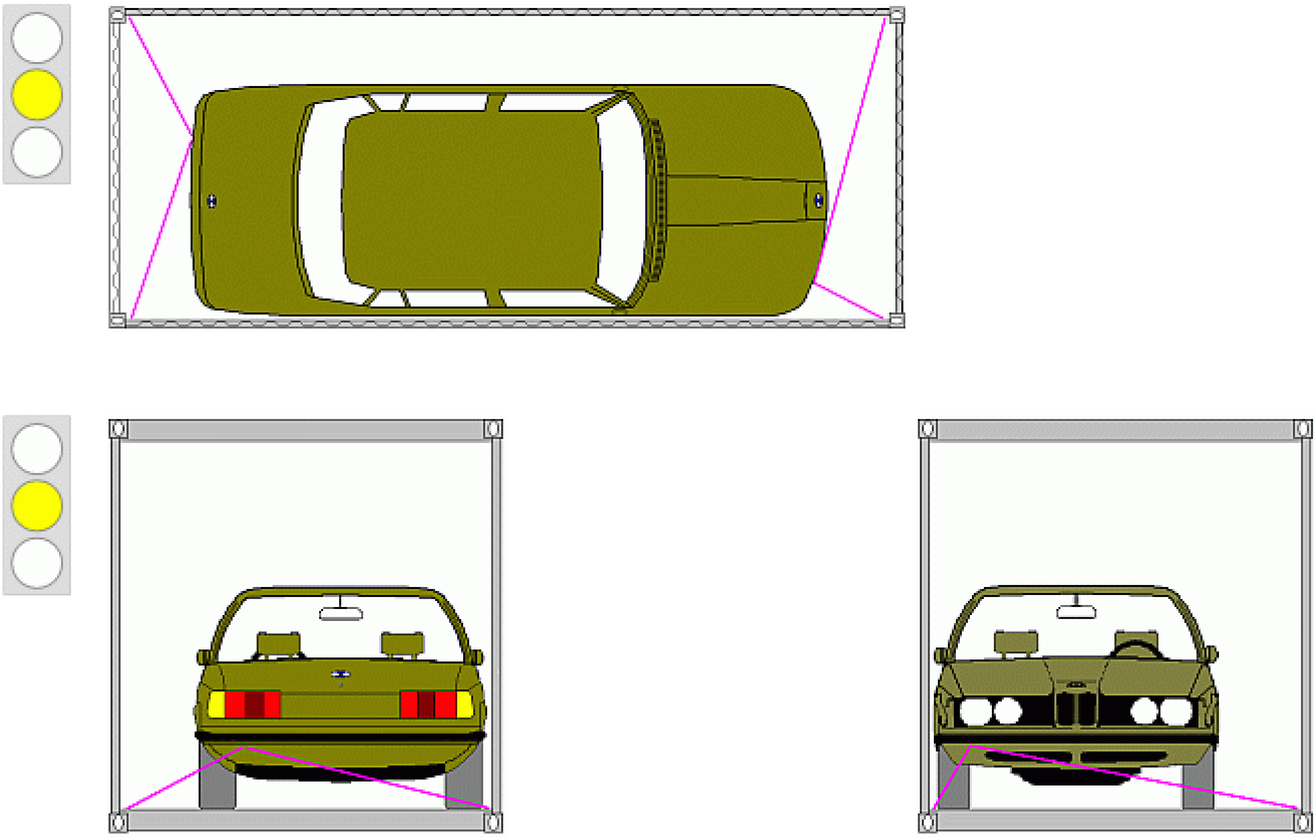
The ideal positions for lashing points on a vehicle are shown in the Figure. In practice they are not generally in these positions.

To achieve a uniform lashing angle, the fastening points on left-hand drive vehicles would have to be fitted symmetrically at front and back but somewhat eccentrically relative to the left-hand side of the vehicle. On right-hand drive vehicles, which would have to be driven up close to the left-hand container wall, the lashing points would have to be arranged somewhat to the right of center.



Lashed automobile in a 20' box container
viewed from the door end and the front end wall

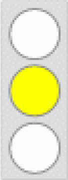
Very often, vehicles only have inappropriately fitted tow eyes as lashing points, for example back right and front right, back left and front right and similar combinations. If this is the case, the lashing angles with which an automobile is secured in a container are inevitably different.

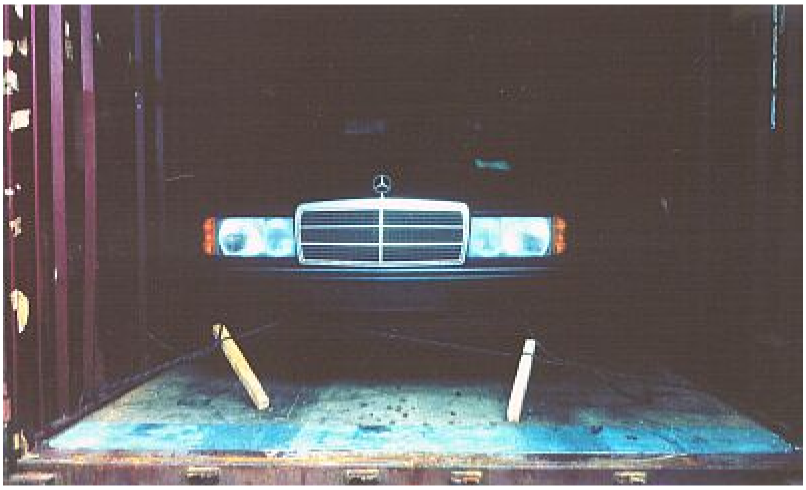


Asymmetrical lashing angles resulting from inappropriate arrangement of tow eyes or lashing points

However, damage is most frequently caused to automobiles in containers not as a result of inadequate securing but as a result of carelessness during driving in and out and during working in the cramped conditions inside the container.

For various reasons, sufficiently stable and/or easily accessible lashing points are often not present on vehicles. Moreover, the preparatory work carried out on vehicles, such as covering the driver's seat with protective film, does not in practice meet current requirements. Here is an example:

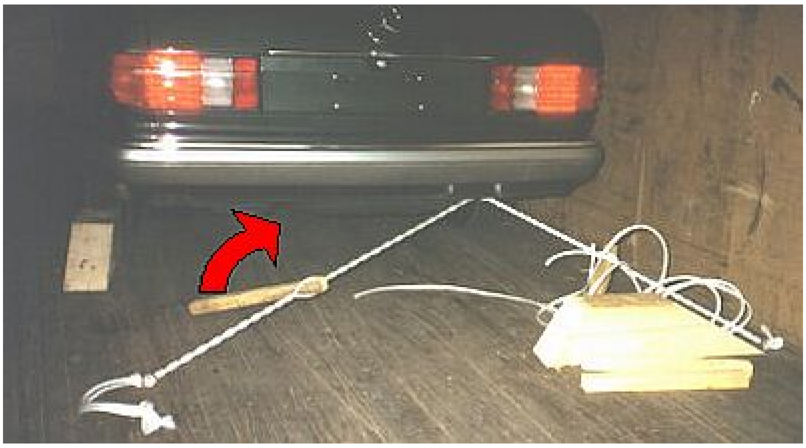




Automobile securing with unfavorable angles

The lashing points on the vehicle would have ensured uniform angles, if the vehicle had been driven forward into the container. However, the vehicle was intended for South America, where vehicles are often damaged during reversing out of the container. The shipowner thus specified that the vehicles were to be reversed into the container in Germany. Since it is also a requirement that the driver get in and out through the driver's door only, and only the driver's side was protected by a film covering, it was only possible to drive the vehicle so its right-hand side was against the left-hand container wall. If the lashing points had been fitted symmetrically and at the same time the passenger side had been covered with film, such vehicles could be parked against the right-hand container side: symmetrical lashing angles would be the positive result.

"Hercules" rope interwoven with polypropylene was used for securing by means of a "Spanish windlass", which is an extremely reliable and quick method. However, it is extremely important for the tightening spar to be secured against coming undone.



Incorrect use of a tightening spar

The left-hand tightening spar is positioned centrally. The rope turns are evenly distributed on both sides, as they should be, but the winding could come undone. The tightening spar should therefore have been longer. The wooden members or wedges have no business to be in the container. Blocking wheels with wedges or lumber nailed laterally against the wheels does not constitute sensible cargo securing, since there is too great a risk that the tires will be damaged when the material is inserted or that the tools used will damage the paintwork or make small dents.

Unfavorable angles
- tightening spar not secured against coming undone -
use of wheel wedges

The wooden wedge, which has moreover been incorrectly cut, has no doubt been used because the lashings have a very small longitudinal component.

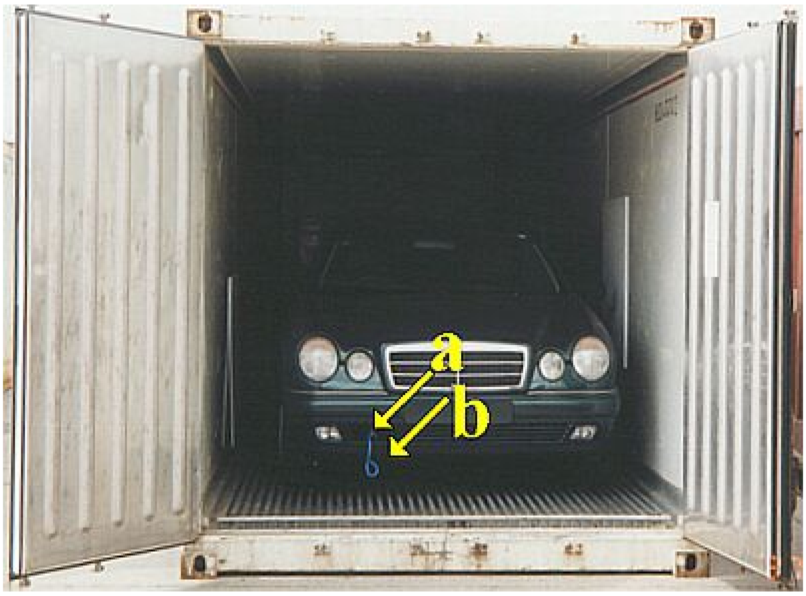
More favorable transverse components due to the
existence of two lashing points on the automobile

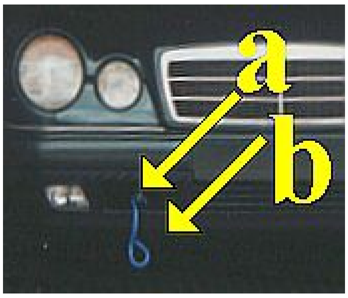
If the automobile had two lashing points at front and back, it could be far better secured than when only one lashing point is available at each end.

Longitudinal components improved
by different positioning of tow eyes

Two lashing points at front and back allow greater flexibility in the fixing of lashings.

N.B. With all of the above methods, there is a risk of the tightening spar coming undone. If this risk cannot be combatted, the use of prefabricated rapid-tightening systems is recommended. However, using them is more cost-intensive.

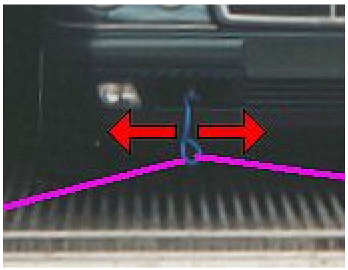




Above and selective enlargement to the left:

Automobile in a refrigerated container: "modern" securing hooks

Many lashing lugs (a) are hidden behind removable flaps. Lashing hooks (b) have to be hung in these hidden lashing lugs (a) for lashing the vehicles.



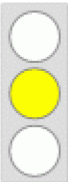
Above and selective enlargement to the left:

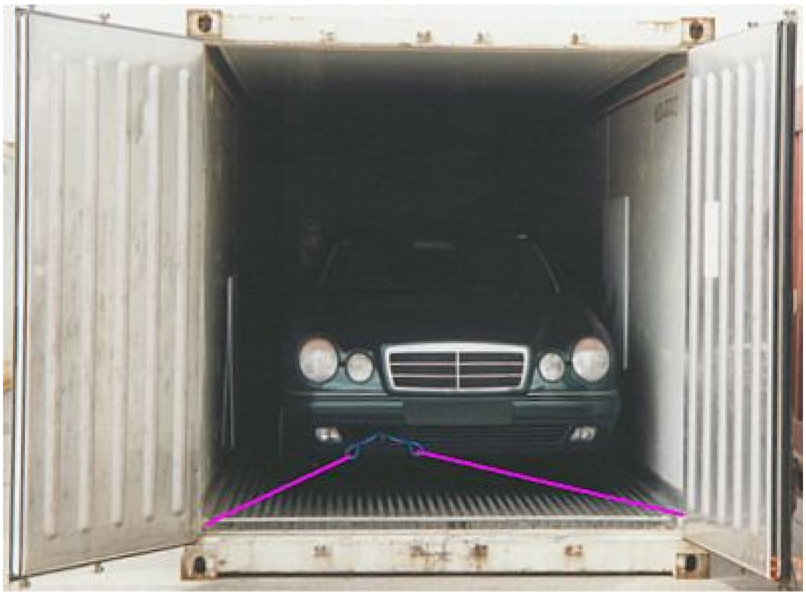
Risk of damage due to "modern" lashing hooks

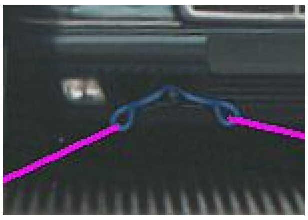
Because of these hooks, in which two lashings have to be hooked and fastened, the vehicle has a degree of "play" to the left and right (see red arrows) and can move to and fro.

It should be pointed out that such impractical methods are used by a very large number of automobile manufacturers, many being very much less suitable than those described here. Many automobiles do not have any lashing points and have to be lashed by the wheel rims.

If two hooks could be fixed to the lashing lugs, vehicles would be fixed appropriately by the lashing means used, provided that the angles and resultant force components conform to shipping stresses.







Above and selective enlargement to the left:

possible method of fixing a vehicle using two lashing hooks in the lashing lug

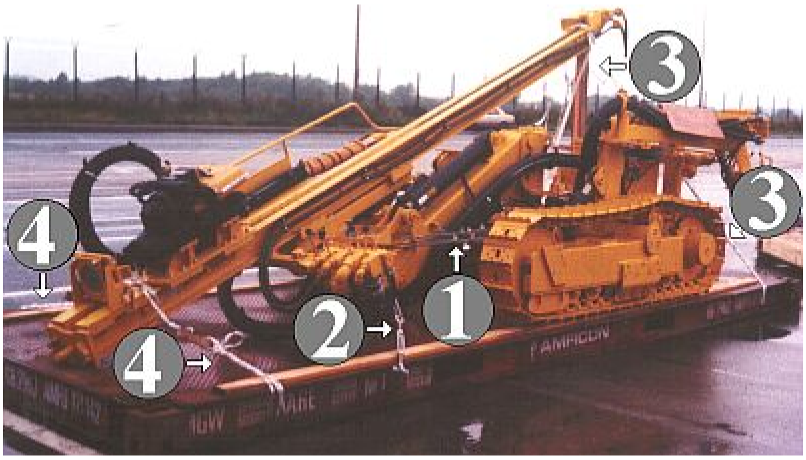
Above and selective enlargement to the left:

sensibly fitted lashing lugs and hooks

With two lashing lugs and hooks at back and front, the vehicles would be appropriately equipped for securing.

.2.4.2 Earth borer on 20' platform

The earth borer is adequately secured on the platform. A couple of generally positive features are that wooden planks have been laid under the vehicle's tracks, to increase the friction between platform floor and machine, and that only direct lashings were used.

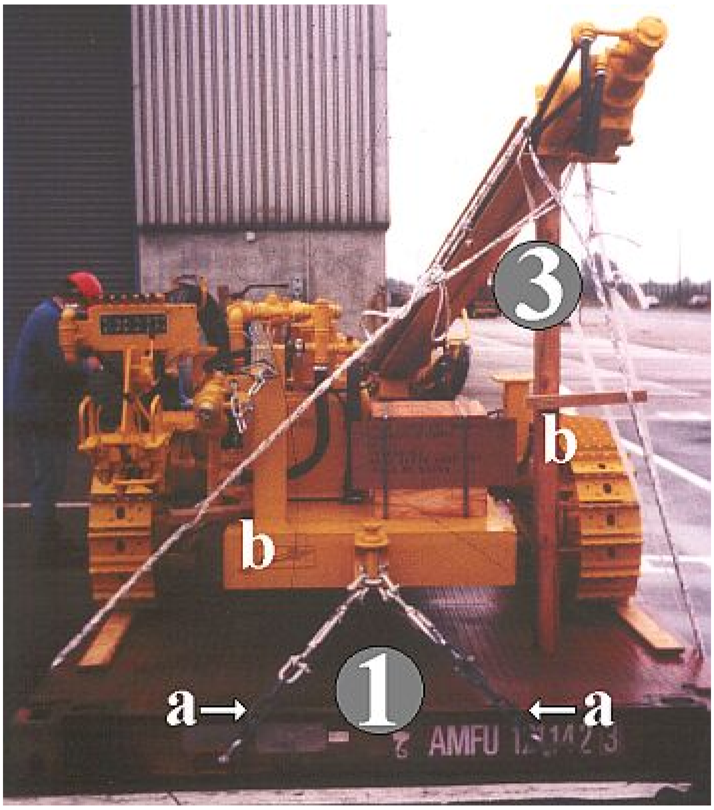


Earth borer on platform

The running gear was secured at the rear (see next Figure) with turnbuckles used as diagonal lashings and (see Figure above) to the tracks by means of oblique and diagonal lashings consisting of steel wire rope (1). The lower part of the boring mechanism was secured with diagonal lashings consisting of shackles, turnbuckles and steel wire ropes (2). The boring arm was fixed at the rear (3) and front (4) by applying Spanish windlasses to oblique lashings consisting of "Hercules" rope interwoven with polypropylene.

Inappropriately fitted lashings (2)

The lashings (2) are inappropriately fitted. It is clear that the turnbuckles are stressed to the point of slight bending. Although, in this case, this does not impair safety, it may prevent the turnbuckles from being reused subsequently. It would have been better if, as in the next picture at (1), the turnbuckles had been attached to the lateral frame of the platform using chain links, i.e. in this instance small pieces of high-strength, long link chains (a). If deflections around sharp edges are necessary, short link chains would be more appropriate, because they would not then be stressed by bending. However, they can only be used as high-strength chains in conjunction with special end links, since no suitably strong shackle can be screwed into short link chains.



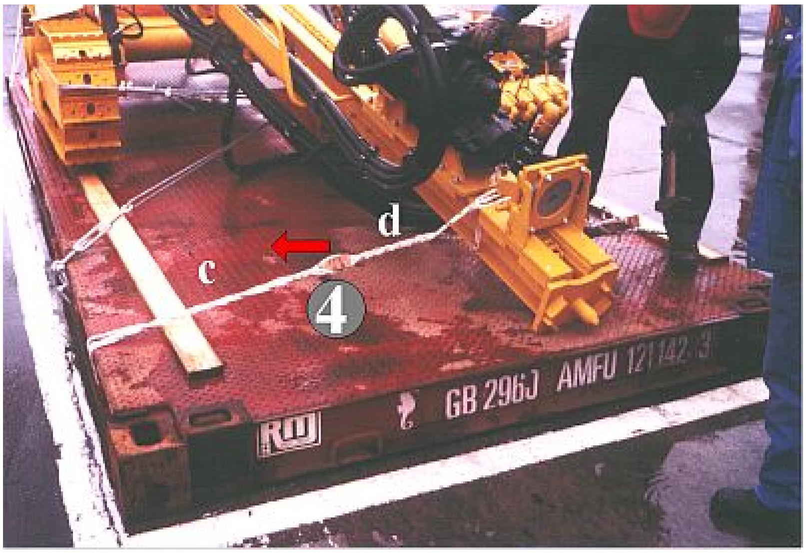
View of the back part of the secured earth borer

The selected lashing angles of the lashings (1) are very well balanced. They provide markedly uniform transverse, longitudinal and vertical components. The lashing angles of the lashings (3) of the boring arm, on the other hand, have an uneven effect. Different positioning of the boring arm was not possible, however.

In this case, securing is only insignificantly impaired thereby, since the lashings (4) produce adequate transverse components for lateral securing of the boring arm. Positive features of the previous Figure are the positioning and fastening of the tightening spars (b): they are prevented from coming undone.

Earth borer on platform - view from the other longitudinal side

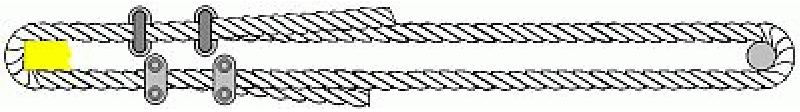
Things are different on the side of the lashing (4) facing the direction of view. Here the tightening spar should have been positioned a little further to the left.



Tightening spar position at (4) in need of improvement

At (c), the number of turns is distributed over a greater length than at (d). Moving the tightening spar a little to the left would have produced more even turns and firmer positioning of the tightening spar.

Wire rope lashings attached to the tracks



Correct wire rope shear

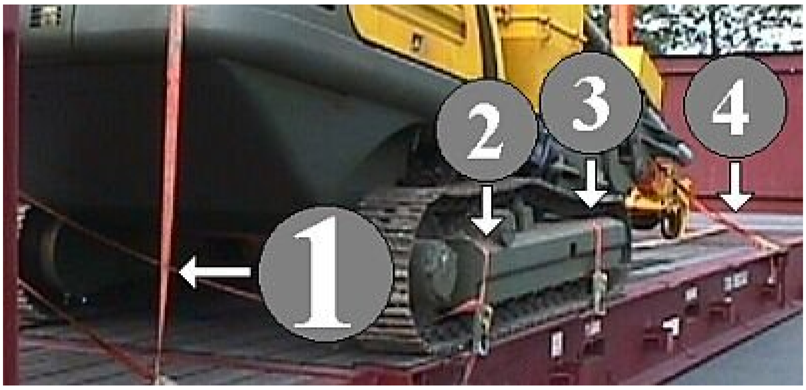
The type of shear ensures that the full maximum securing load of the wire rope is retained at the sharp edge because four working parts are produced which each provide 25% of the full strength.

However, a possible criticism is the thickness of the wire ropes used. Since the maximum securing loads of the lashing points present ranged from 3,000 daN to 4,000 daN, material is wasted by using wire ropes with a diameter of 16 mm, since maximum securing loads of 10,240 daN can be achieved with such wire ropes.

5.2.4.3 Earth borer on 40' flatrack

Inadequately secured earth borer on a 40' flatrack

It is obvious, even at first glance, that the earth borer is inadequately secured and its center of gravity is eccentrically positioned. The apparatus will slip during road or terminal transport and, unless improvements are made, there will be an acute risk of damage during a voyage.

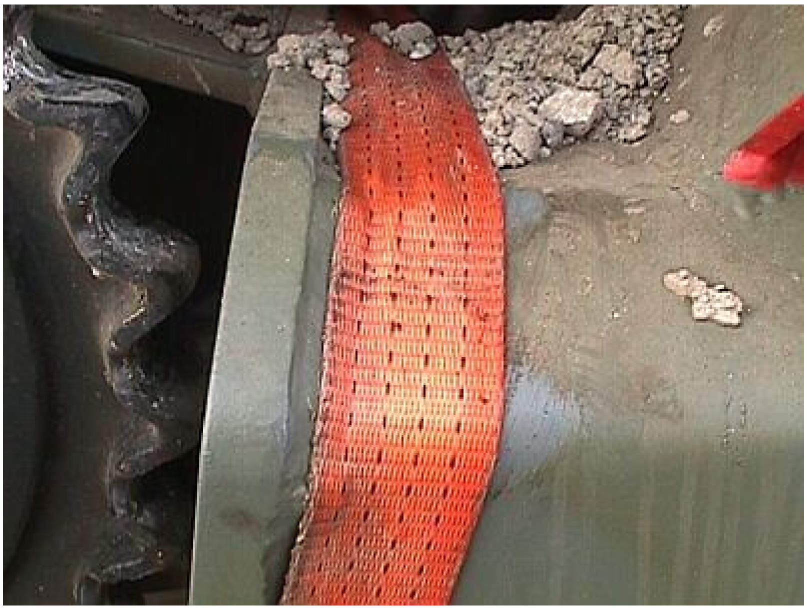


Top and selective enlargement below:
Loosened, slipped lashing belts

The lashing belts (1) and (4) have clearly slackened. The lashing belts (2) and (3) have tightened up due to displacement of the machine.

Ineffective, incorrectly applied lashing belt

The way the belts have been applied, they are capable of absorbing virtually only vertical securing forces and act only against upwards movement. It is incorrect to pass belts through the louvers in the engine compartment cover serving as a counterweight in such a way that they are constricted and thereby weakened. The fittings on the belt are not entirely suitable for attachment to the steel stirrups visible on the flatrack.



Lashing belt weakened by sintering

The lashing belt (2) has been stretched by the movement of the earth borer on the flatrack. Slippage produced so much energy that paint was rubbed off and the belt material was damaged by frictional heat. Allowing stones to get under the belt is sloppy practice and could weaken the belt. The fact that the appliance has already slipped during precarriage shows that the tie-down lashings used for cargo securing were unsuitable.

Lashing belt weakened by slippage

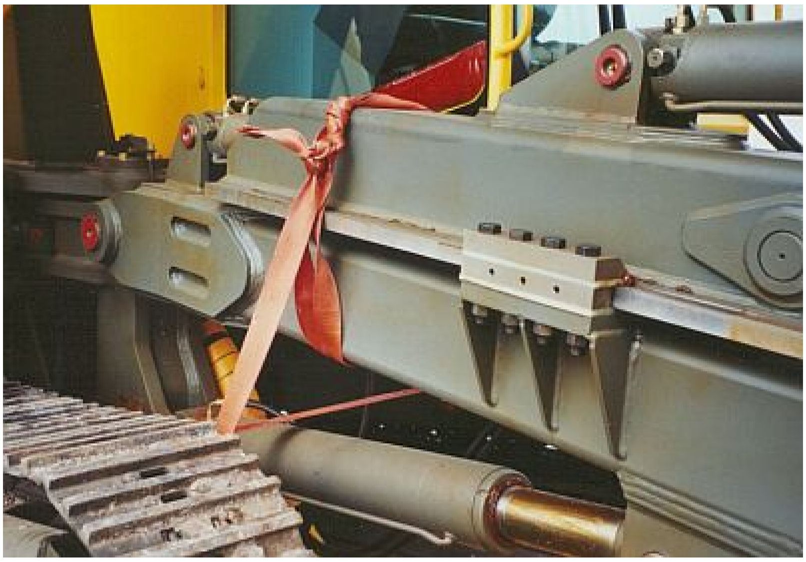
Lashing belt (3) also shows slight damage due to shifting of the earth borer caused by inadequate securing.

Inadequate securing of the boring arm by a round-turn lashing

A part can move relatively freely in a round turn. In this case, the boring arm can consequently move easily to the left and right, if it is not prevented from doing so by a bolt in the turning gear. This deficiency could be remedied by two loop lashings.

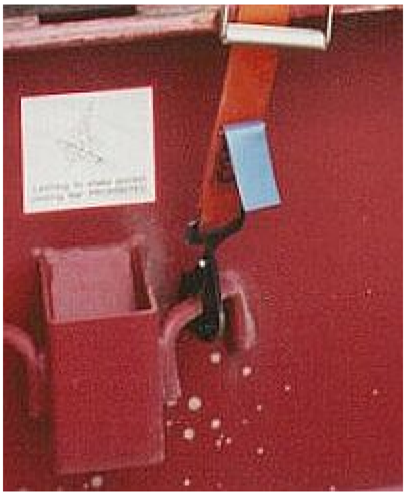
Above and selective enlargement to the left:

Incorrect use of lashing belt (5)



It is forbidden to knot lashing belts.

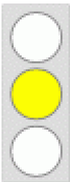
If lashing belts are knotted, up to 70% of the admissible lashing force F_{adm} or the lashing capacity LC stated on the belt label is lost. Even specialists don't know what strength is actually left.

Misused and appropriately used lashing hooks

The lashing hook of lashing belt (5) has also been incorrectly used. It is not intended to be used in the manner illustrated on the left. If the opening in the hook is big enough, the hook can be used as illustrated on the right. The load borne by the hook must be applied to its base.

The manufacturer of the earth borer has not taken any precautions with regard to cargo securing, despite being well aware that the machine does not travel to its purchaser or place of use on its own tracks. Cargo securing is therefore particularly difficult and risky. Cargo securing personnel seldom know which parts of the machine can be loaded to what degree and in what manner and such information can often be difficult to obtain. The following recommendations for appropriate securing are therefore made with reservations and without any guarantee that they are correct:



Basic principles of securing the earth borer

Appropriate longitudinal securing means (purple), transverse securing means (blue) and vertical or anti-tip securing means (green) must be provided, in addition to appropriate load distribution. The following more detailed options are feasible:

1. The earth borer is positioned on the flatrack in such a way that the overall center of gravity of the machine lies as far as possible within the central longitudinal and central transverse line of the flatrack.

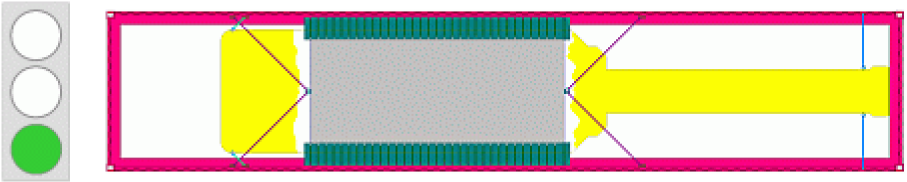
2. Sufficient longitudinal components need to be produced for cargo securing. To this end, as indicated by purple lines, lashings are attached to the inside of the tracks with sufficiently broad fastening elements and tightened in the longitudinal direction of the flatrack with as flat as possible lashing angles. As an alternative, bracing could be provided between the earth borer and the ends of the flatrack. Given the large distances to the end walls, this method is only economic if no lashings have to be attached to the tracks.

3. Sufficient transverse components need to produced for cargo securing. To this end, as indicated by blue lines, lashings are attached to the inside of the tracks with sufficiently broad fastening elements and tightened in the transverse direction of the flatrack with as flat as possible lashing angles. Before the tracks are used for load securing, it should be clarified in each individual case with the manufacturer of the construction machinery whether they can withstand the loads applied by load securing. To secure the boring arm, appropriate loop lashings need to be selected which are passed in each case from right to right and left to left to separate lashing points. As an alternative, lateral securing is possible by inserting the stanchions of the flatrack in the area of the tracks and bracing small gaps between tracks and stanchions with boards.

4. To secure against tipping, appropriately shaped fittings can be hooked into the solid metal louvers of the engine housing. Direct lashings are hooked into these fittings to secure against tipping and vertical movement.

Similar provision is made at the front of the earth borer. However, electric or hydraulic lines must not be impaired in any way.

If the manufacturer of the earth borer had provided adequately sized lashing points on the running gear, the counterweight with engine housing and the boring arm, appropriate securing could easily have been achieved.



Problem-free securing of an earth borer suitably designed for transport

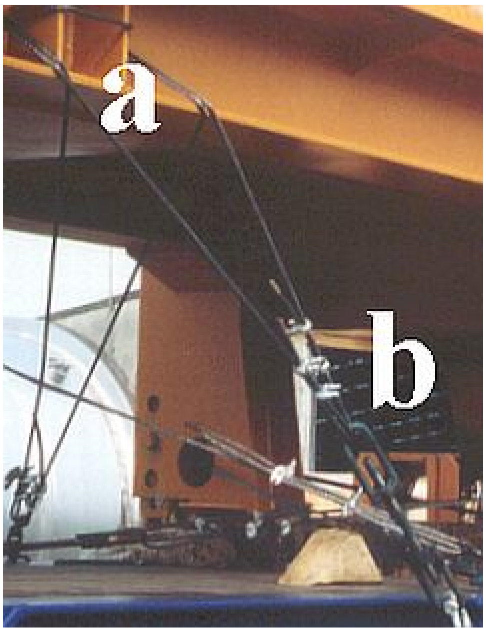
5.2.4.4 Concrete breaker on 40' flatrack

Adequately secured concrete breaker on a 40' flatrack

Once again, the manufacturer had not taken any precautions with regard to transport and cargo securing, resulting in particularly high material and labor costs when it came to securing the concrete breaker. Some areas of the vehicle could not be used for cargo securing, because they had hydraulic and electric lines running along them. Some correctly placed, appropriately dimensioned lashing points would have simplified cargo securing operations tremendously.

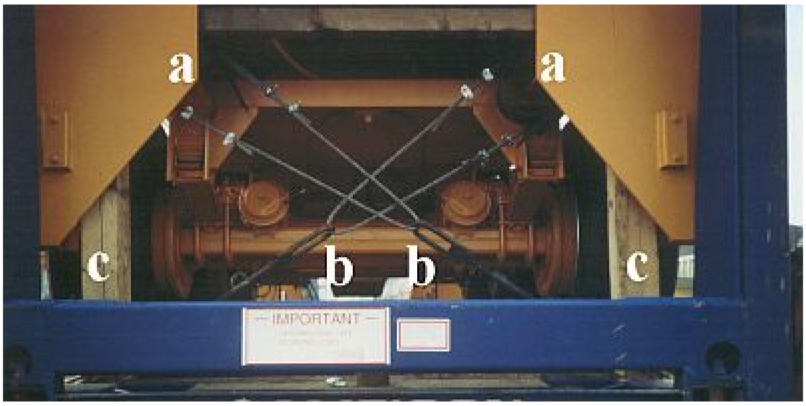
Oblique view of some securing measures

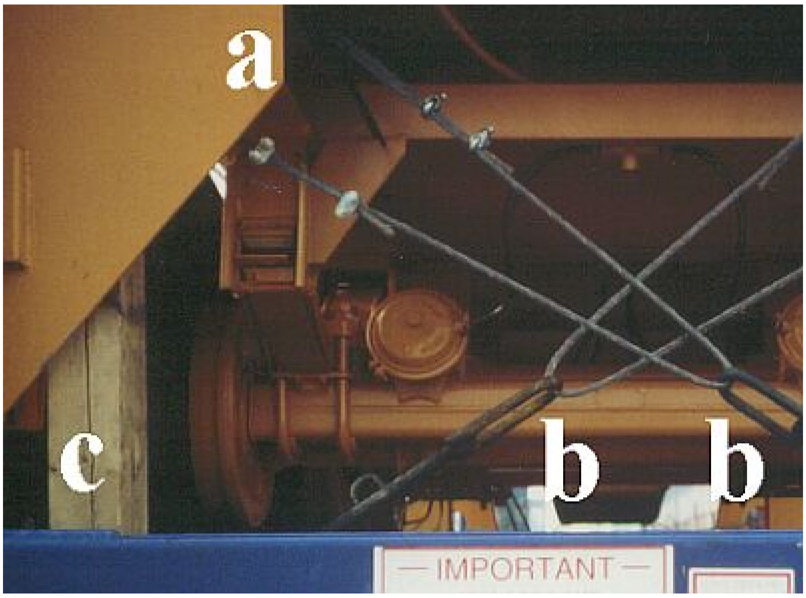
At the sharp edges of the breaker components, the maximum securing load of the wire ropes was reduced by approx. 50%, but no other fastening arrangement was possible due to the design of the breaker.



Lashing problems caused by the breaker design

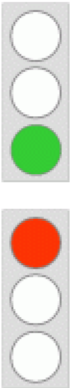
In order to achieve uniform lashing, quadruple cable shear should have been provided at (a) and double shear at (b). However, this was impossible because of the very narrow openings provided by the design. The length of the wires hindered manual pretensioning. As a result, a very large number of turns had already been used when it came to actual pretensioning by means of the turnbuckles.





Top and selective enlargement below:
Correct arrangement of wire ropes

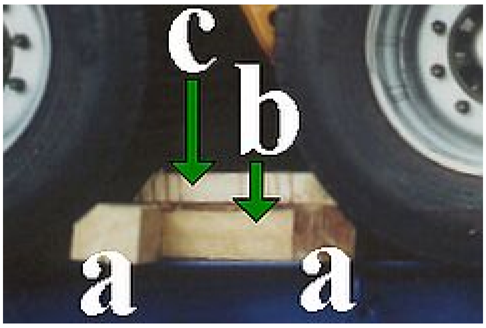
At the rear part of the vehicle, it was possible to fit the wire ropes correctly. Quadruple shear is produced by the sharp edges at a, and double shear at the turnbuckle stirrups b. A positive feature in the Figure is the blocking up of the vehicle off its suspension by means of the squared lumber c, so preventing unnecessary vibrations of the vehicle and abrupt loading of the lashing wire ropes.



Lengthwise securing using wedge members

The wedge members, among other things, contribute to lengthwise securing of the vehicle. This effort could have been spared, if the breaker had had appropriate lashing points: adequate securing could have been quickly and cheaply achieved with oblique lashings. The misshandling of the flatrack with the tines of a forklift truck at (I) was far from "gentlemanly".

There is a knack to producing tight fitting wooden assemblies.



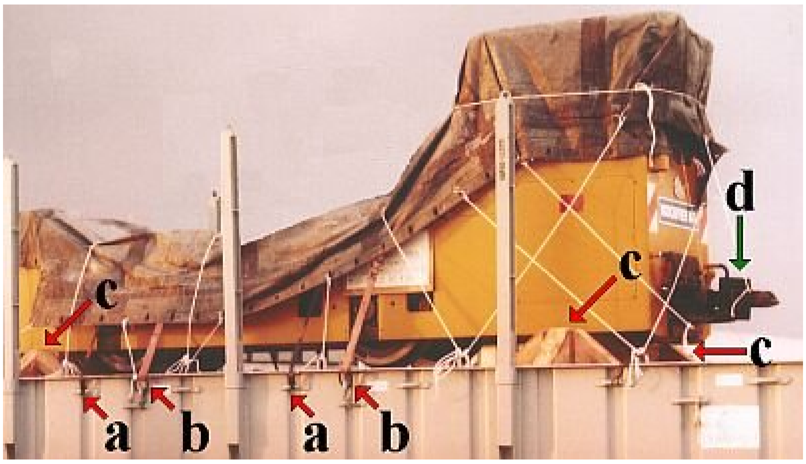
Wedge member bracing between the tires

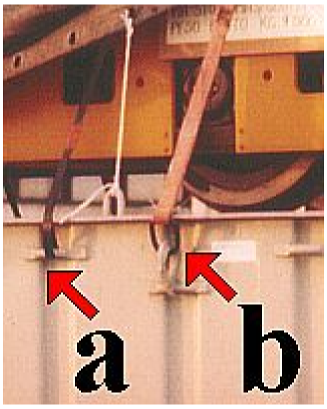
First of all, the two wedge members a are inserted crosswise between the tires on the axle. An auxiliary member, not shown here but whose length matches the gap between the members a, is cut to size, inserted between the wooden members and driven apart towards the tires with driving wedges. The then somewhat enlarged gap is measured and the wooden member b is cut to this size and fitted. Once the dimensions for the securing member c have been determined, this member is cut to size and likewise fitted. Finally, the driving wedges are knocked free and the auxiliary member is removed. The wooden bracing is held firmly in place due to the elasticity of the tires, without any nailed joints.

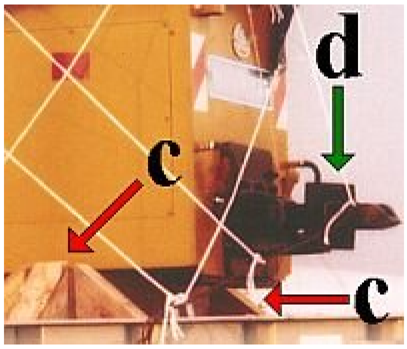
Slot for the flatrack on board ship

This picture illustrates just how important it is to secure each cargo appropriately, even in the vertical direction. The flatrack is positioned in the last bay of the ship and will experience the greatest vertical accelerations during pitching at sea, as well as the other movements of the ship.

5.2.4.5 Rail vehicle on 40' flatrack







Top and selective enlargements below:
Inadequate securing of a rail vehicle

The vehicle cannot be held securely by the four tie-down lashings applied. Two consist of steel strapping (a) and two of textile belts (b) from the lashing reels fixed to this flatrack. The wooden wedges (c) do not have any great securing effect.

This example gives cause for much criticism:

1. Although the manufacturer of the flatrack has installed lashing reels, they are all on one side and can only be tensioned in the transverse direction. If the lashing reels had been installed evenly or alternately on both sides, the vehicle could have been secured against transverse acceleration with two loop lashings on each side. If the structure of the reels allowed the lashing means to be tensioned in the longitudinal direction or obliquely as well, securing against forces in this direction would have been possible.

2. The manufacturer of the vehicle omitted to install appropriate lashing points on the vehicle. The apparatus cannot be deemed fit for transport without them. Their provision would result in a marked reduction in the risk of damage during transport.

3. It is clear from the securing provided that the packing company used untrained personnel.

Despite the lack of other lashing points, the vehicle could have been appropriately secured with loop lashings and direct lashings at the coupling, which requires blocking, and/or with wooden bracing against the stanchions.

5.2.5 Cargoes in barrels

Section 3.2.3 of the CTU packing guidelines provides a useful introduction to this topic:

> *Where cargo of regular shape and size is loaded, a tight stow from wall to wall should be sought. However, in many instances some void spaces will occur. If the spaces between the packages are too large, then the stow should be secured by using dunnage, folded cardboard, airbags or other suitable means.*

Some information has already been provided about barrels in the "Basic stowage methods" section. This section uses individual examples to point out securing options and covers particular points which have not been dealt with sufficiently clearly previously.

Packing a container with barrels on pallets

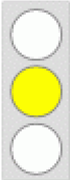
The wording "packing a container with barrels on pallets" has been chosen deliberately, as the barrels have not been palletized, for which they would have had to have been firmly connected to the pallet. Here, the pallets serve on the one hand to rationalize handling and on the other hand as floor and interlayer dunnage. Care is recommended if the dimensions of the barrels do not exactly match those of the container, since stowage gaps are then left which absolutely must be adequately filled.

Packing progresses

Dented barrels should be checked to ensure that the dents do not occupy so much of the volume of the barrels that they may burst as a result of expansion due to heating.

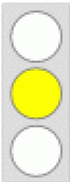
Wooden lattice for securing in the door area

If the dimensions of the barrels are such that they fill the container to the extent that it can be packed right up to the door, a lattice consisting of vertical boards (a) and horizontal squared lumber (b) is prepared outside the container and positioned in front of the batch. The vertical boards should be positioned precisely centrally against the barrels, so that they assume the task of load transfer precisely at the strongest points of the barrels, namely the



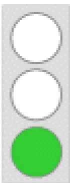
It is distinctly less advantageous to construct the lattice from horizontal boards (a) and vertical squared lumber (b), because fewer contact points are available overall.

Less favorably constructed wooden lattice



To achieve the same number of contact points as with the first lattice, considerably more material would have to be used.

Wooden lattice using too much material



Shoring in door area - fitting of oblique bracing (c)

If a gap is left because of the cargo dimensions, the lattice has to be braced towards the door. This may be achieved on the one hand with horizontally/obliquely fitted squared lumber, which is positioned against the corner posts or, as here, with shoring. To this end, squared lumber members (c) are placed against the feet of the vertical lattice members and positioned obliquely against the top door rail.

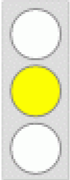
Shoring in door area - fitting of horizontal members (d)

Wooden members are fitted at each layer in the longitudinal direction between the oblique shoring and the horizontal members of the lattice.

Inadequate securing of barrels in door area

A "lattice" fitted like this cannot prevent the barrels in the top layer from shifting. The vertical boards are only there to hold the horizontal squared lumber in position. The barrels rest with their body, the most sensitive part of a barrel, against the squared lumber.

Closing a container packed with poorly secured barrels

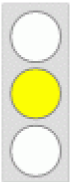


Packing a container with pails or small drums

Interlayer dunnage made of hardboard or thin chipboard is positioned at (a). The main purpose of the boards is pressure distribution. Instead of tiny contact points between individual drums, the weights are distributed over circular strips of the drum rims. Further details about this problem may be found in the section on Static mechanical stresses.

Point 4.3.6 of the CTU packing guidelines is highly relevant to the next packing example:

> *Drums containing dangerous cargoes should always be stowed in an upright position unless otherwise authorized by the competent authority.*



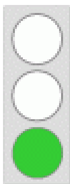
Slight shortcomings

Shortcomings eliminated

Point 4.2.7 of the CTU packing guidelines states, among other things:

> *Packages of dangerous cargoes should be examined and any found to be damaged, leaking or sifting should not be packed into a CTU.*

The drum or barrel indicated in red is dented. To what extent that already constitutes damage cannot be settled conclusively here. The frame is at risk from the top layer of barrels, for which reason the frame has been reinforced (a) and the barrel replaced (B).



Unsecured barrels

Secured with shoring

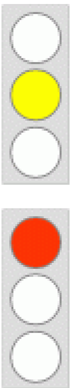
Barrels containing hazardous materials must not be packed in the manner shown and even for barrels with normal contents it goes against "standard stowage practice". At any rate, they cannot remain unsecured. Safety can be ensured with shoring.

In the section headed "On completion of packing", point 3.3.1 of the CTU packing guidelines reads as follows:

During the final stages of packing a CTU, care should be taken, so far as is practicable, to build a secure face of the cargo so as to prevent "fall out" when the doors are opened. Where there is any doubt as to the security of the cargo, further steps should be taken to ensure security, e.g. by weaving strapping between securing points or placing timber [lumber] between the rear posts.
Two factors should be borne in mind:

- *that a container on a trailer usually inclines towards the doors; and*
- *that cargo may move against the doors due to jolts, etc., during transport.*

The main reason for this requirement is to ensure that, when a CTU is opened, in particular when a container is inclined towards the doors, no one is endangered by items of cargo falling out. This objective can be achieved only to a very limited degree by the cargo securing illustrated.



Incorrectly arranged securing material

Since the single-use textile belts have only been fitted in the upper area of the barrels, the barrels, can slip out at the bottom. Given that this form of securing has been selected, the strapping should have been attached at least around the upper and lower thirds of the barrels. The amber traffic light is thus intended to signify "Caution".

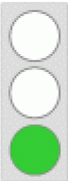
The actual implementation and working method in themselves are given a red light. The belts are tightened only across the cargo end face, so generating angles of spread of virtually 180°. This means that the slightest shift in the longitudinal direction may exert extremely large forces on the belt material. This is particularly true of the middle barrels, against which the belts lie completely straight. The angle of spread amounts to 180°, the tangent to 180° is infinite, meaning that the securing force provided by the belts is virtually zero. If such securing means are to be provided, care must be taken to ensure that the fastening belts extend as far as possible into the interior of the container. In this way, the angle of spread (at the outer edges) is avoided and direct securing is produced. However, this does not solve the problem for the middle barrels and should therefore not be used to secure barreled cargoes unless additional aids are provided such as wooden members attached transversely in front of the barrels.

In addition, the straps are knotted, which contravenes the relevant technical rules and German accident prevention regulations.

5.2.6 Lumber cargoes

5.2.6.1 Roundwood or logs

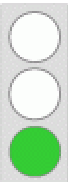
Roundwood can be very easily stowed on flatracks equipped with stanchions. It is better if other open containers or platforms are not used. The fewest problems are caused by individual, heavy tropical logs or blocks. These can be positioned centrally on the transport supports and secured laterally with loop lashings. Longitudinal securing depends on the type of container. Bracing is one option, or lengthwise loop lashings, overhead loops plus oblique lashings or similar methods.

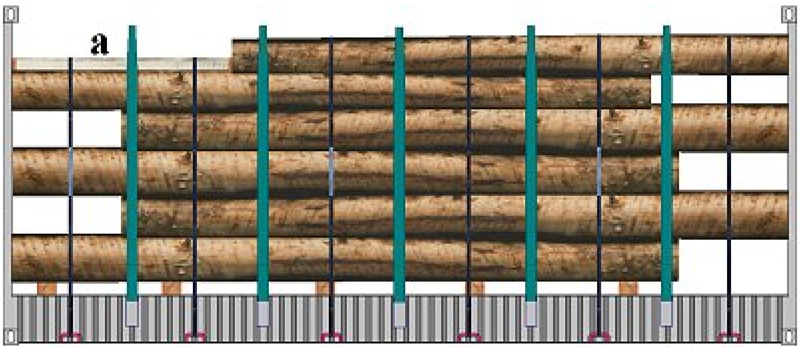


Transverse securing

Lengthwise securing

If lashing rings with an MSL of 6,000 daN are available and chains of a similar grade are used as loop lashings, a 24,000 kg block could be secured with two loop lashings against acceleration of approximately 1 g. Wooden bracing can be used in the lengthwise direction.

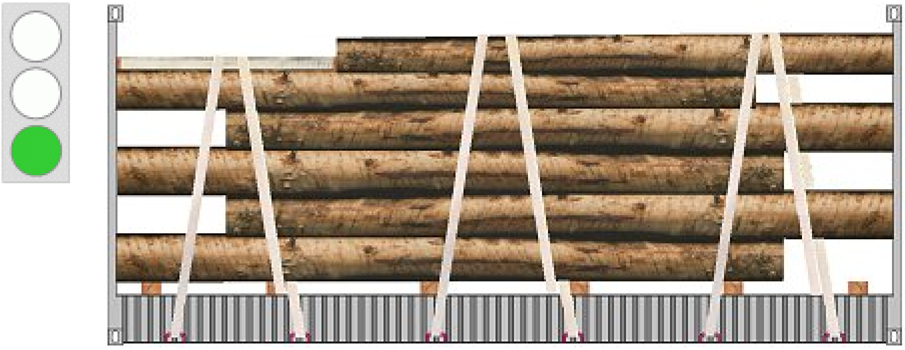




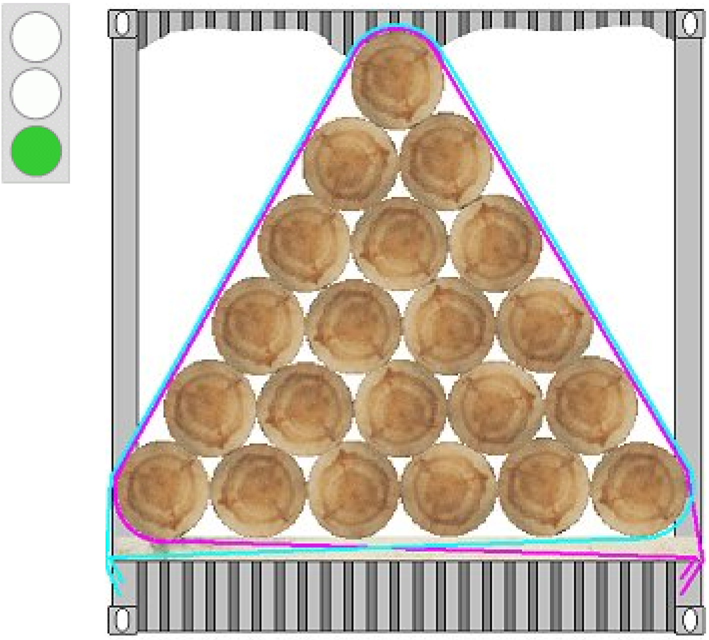
Staggered - wedged together - top gap blocked

The logs were positioned alternately with their thick ends against the end walls, resulting in wedging together of the lower layers. Of course, this only works if the end walls are sufficiently strong. The gap in the top layer is braced (a). In the case of flatracks with stanchions, lashings can be used. Securing with steel strapping is acceptable, if the stanchions are lashed together transversely. However, it is to be expected that the steel strapping will slacken. A resilient material would be better. If tie-down lashings are used, the logs can even be loaded without any transverse underlays. These cannot be omitted if loop lashings have to be used for securing due to a lack of flatracks with stanchions.

This works if the logs are loaded in the cantline.



Lateral securing using loop lashings



Logs packed in the cantline in pyramid stow and secured with loop lashings

Roundwood cargo on a 40' flatrack with stanchions

Although this roundwood cargo is properly secured, too much effort has been put into lengthwise cargo securing, since the wooden bracing at the ends requires a lot of work and material. The securing used at the ends consists of vertical squared lumber, to which boards have been nailed crosswise in the form of a lattice. Squared lumber braced lengthwise between the vertical squared lumber lies on each of these boards. The logs have been packed in such a way that they rest with their largest diameter on one another and against the stanchions, so meaning that they are not positioned in the cantline directly against the stanchions. The maximum securing load of the blued 1.6 mm x 32 mm steel strapping matches that of the lashing points.

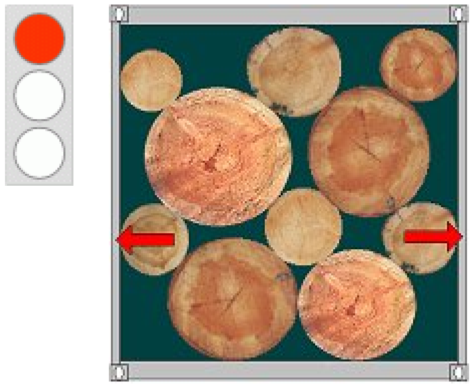
The stanchions, which are bound together in the transverse direction, effect transverse securing. Steel strapping effects vertical securing. Slack is to be expected in the steel strapping. Load distribution still falls within legally admissible limits, despite the fact that the thick ends of all the logs point in the same direction.

The following variant is somewhat cheaper but still very complex. Load distribution is definitely within regulatory limits.

Load distribution good - cargo securing effort high

Prior to packing, a lattice of squared lumber and boards is prepared and so dimensioned that the logs on the flatrack are still caught by the stanchion furthest to the left. The lattice is placed against the right-hand end wall and the logs are stowed tightly against it. The gap to the left is braced by two lattices plus squared lumber. As before, steel strapping is used for securing.

Correct stowage



Incorrect stowage

When stowing logs in box containers, it must be noted that the logs directly or indirectly load the container walls due to the angles of spread or rest. The logs must be packed tightly against the end walls and so as not to overload the side walls. Gaps at the door end must be braced.

5.2.6.2 Examples - cut and packaged lumber

The most important objective when bundling cut and packaged lumber is to ensure that the materials used for bundling, generally steel strapping, cannot be damaged by handling with forklift trucks and lifting gear.

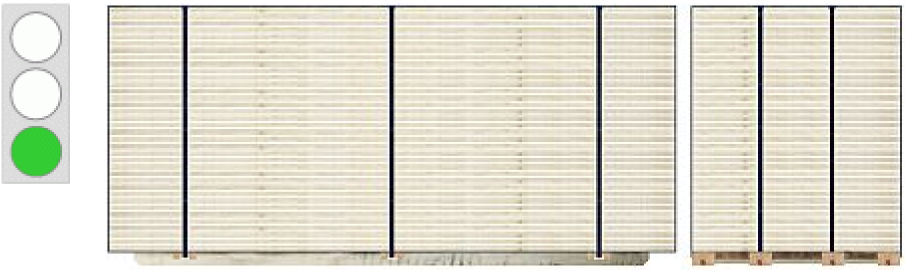
Therefore, only lumber with a routed-out groove should be used as a support.

Expertly fashioned supports

Steel strapping has very little elasticity. This shortcoming may be compensated, for example, by using edge protectors of a material with good recovery. Otherwise, the strapping regularly slackens, since the steel strapping presses into the wood and becomes loose as a result of the reduction in circumference. Steel strapping can only be recommended if it is used in conjunction with such materials. Otherwise, materials should be used which have good, but not excessive, elasticity.

Normally arranged strapped packages

If packages with the usual transverse strapping are moved lengthwise, they should additionally have skids, so that the straps are not torn off during handling.

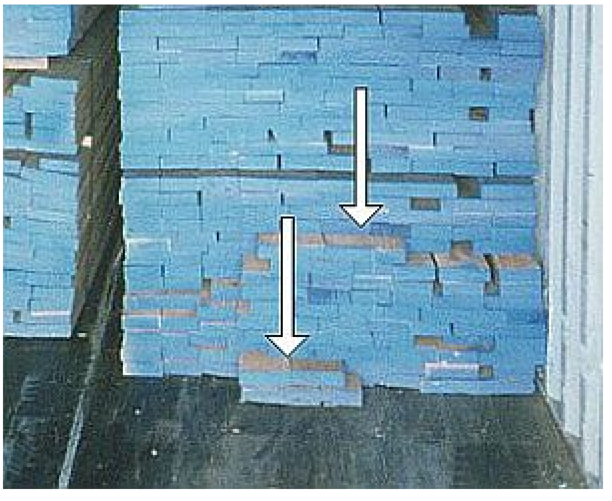


Well organized package base

Here, the lengthwise members have been recessed and the transverse members let into the recesses. In addition, further transverse members have been fitted and the ends of the lengthwise members cut in the manner of skids. All the wooden members have been positioned in such a way that there was no risk of the strapping being damaged by forklift trucks, and also in such a way that lifting gear can be used for lift-on/lift-off operation.

Risk of damage due to inappropriate strapping

Strapping is not suitable for the handling method shown here. The strapping could tear during packing and unpacking, resulting in delays and extra costs.



Cut lumber packages in a box container, enlarged section

It should be noted that the strapping did not withstand the stresses of handling even during loading.

Stowage gaps filled with squared lumber

For trouble-free transport it is important for all gaps to be filled.

If stowage gaps are not filled, the goods will be displaced during transport, possibly resulting in damage to the container and/or goods.

As may be seen from this import container, financial losses are the ultimate result of impeded handling, storage after shipment and onward transportation.

Losses result if gaps are left.

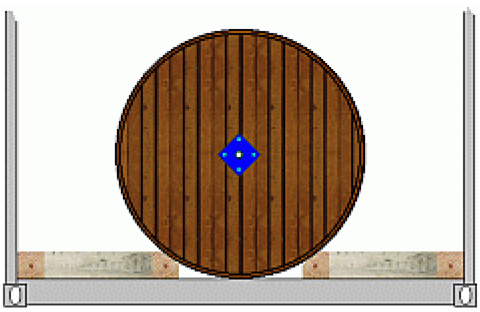
Strapping deficiencies and unfilled gaps regularly lead to deformation of packages.

5.2.7 Cable reels

5.2.7.1 Cable reels in standard containers, winding axis horizontal and lengthwise

Stowage of six larger cable reels in a box container

Smallish cable reels can be secured relatively simply with a tight fit in box containers, provided the containers have an appropriate number of lashing points.

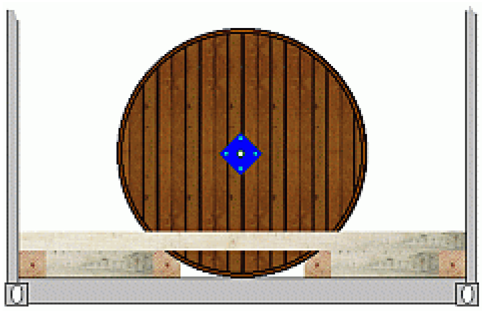


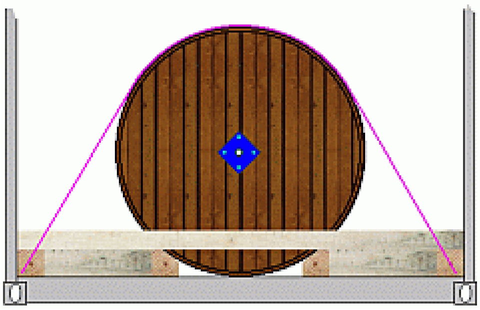
Bed for lateral securing of cable reels

The cable reels are stowed with their axis lying lengthwise. Wedge members are positioned to the left and right, with flank angles which should correspond to the adjacent tangent. Unlike with steel sheet coil stowage, the cable reels lie centrally. For pressure distribution, squared lumber or planks are positioned against the container side walls. It is advisable for the appropriate lashing means to be attached before the wooden members are set in place. Special measures are not generally necessary where the lashing points are fitted between the container corrugations. If the lashing points are recessed into the container floor, the wooden members have to be recessed at these points. Between these wooden members and the wedge members, transverse members are fitted for securing purposes.

Depending on the reel packing pattern, transverse members for subsequent lengthwise securing of the reels are fitted either in front of and behind a cargo block or in front of and behind each cable reel:

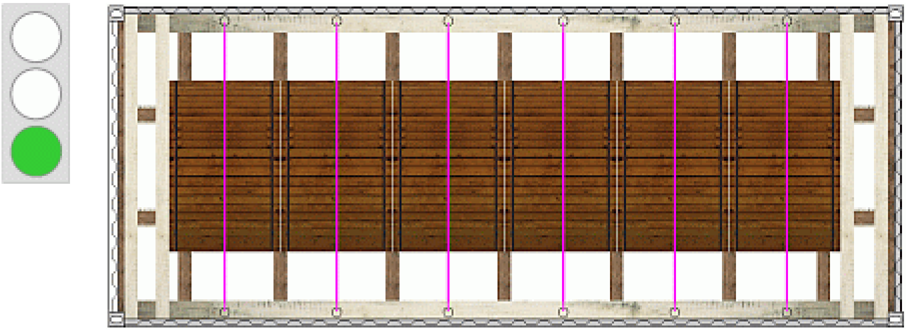
Transverse members for subsequent lengthwise securing of the cable reels





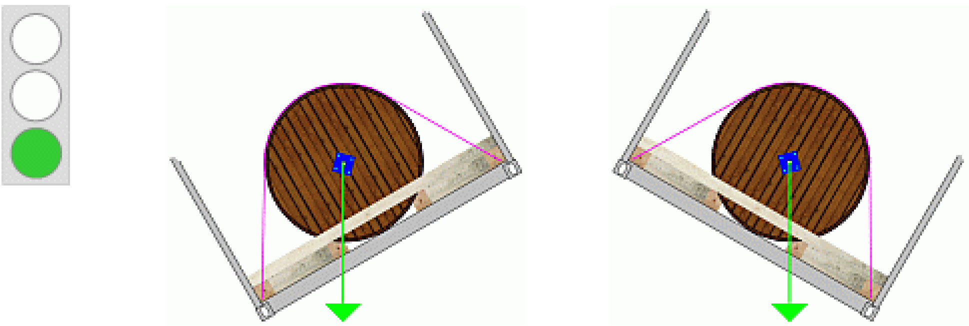
Overlashings preventing the reel from "popping out" of the bed under dynamic loads

Because of the number of cable reels and lashing points, in this example the cable reels are each secured with overlashing to prevent them from "popping out" of the bed under dynamic loads. Given their function, these are not tie-down lashings but direct lashings, so that only moderate pretension may be applied.



Cable reels secured in all directions

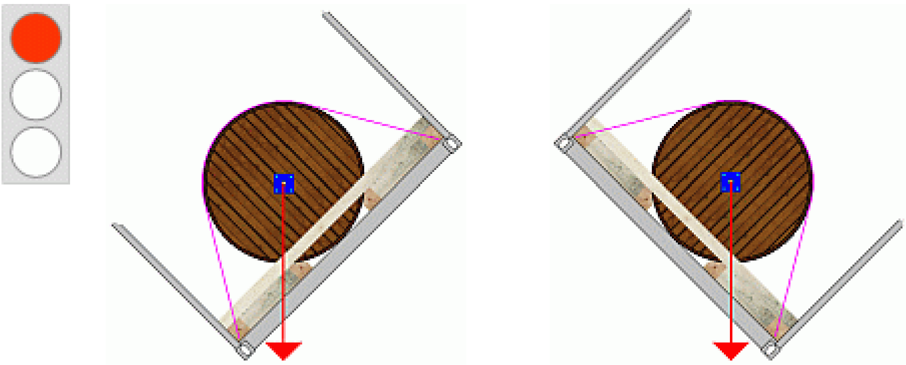
It was only possible to use one overlashing per cable reel but, nonetheless, the reels are adequately secured in the longitudinal and transverse directions, if the rolling angle remains within the usual limits for containers stowed lengthwise (fore and aft stowage).



Weight-force vector at 30° rolling angle

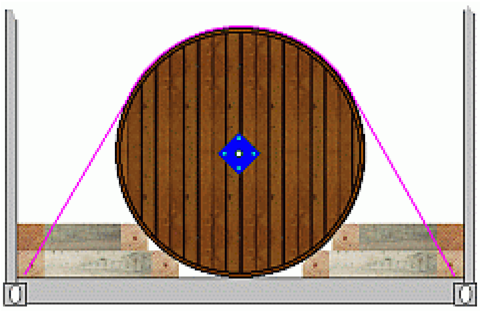
At a tilt of 30°, the weight-force vector corresponds to the line of contact with the wedge members. In this way, adequate lateral securing of the cable reels is achieved.

The picture is different if rolling angles of 45° are assumed.



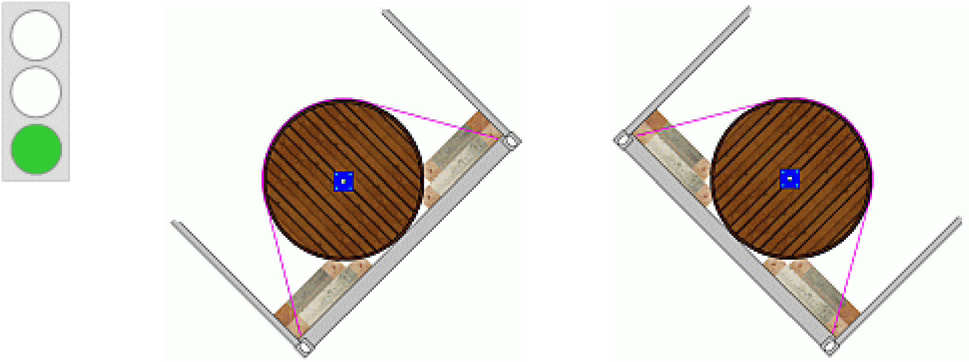
Weight-force vector at 45° rolling angle

At an inclination of 45°, the weight-force vector is outside the line of contact with the wooden wedges. In this way, adequate lateral securing of the cable reels is not achieved. They could roll out of the cradle and, to prevent this, additional lateral wooden members are required:



Additional wedge members and transverse braces for lateral securing

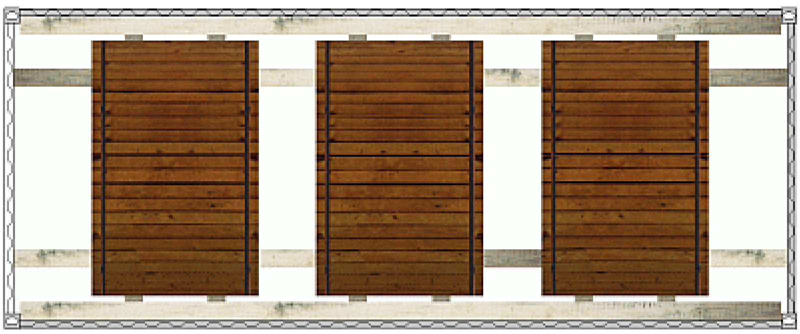
These measures allow the cable reels to be supported further up, so eliminating the risk of cargo shifting:



Adequate securing of cable reels even in the case of a 45° rolling angle

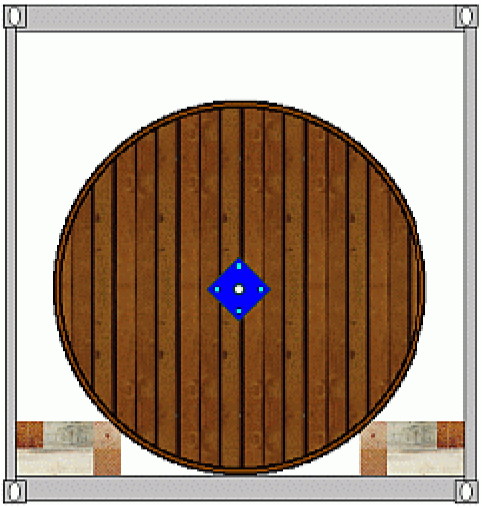
Even with a rolling angle of 45°, the weight-force vector is still within the line of contact with the upper wedge members.

Stowage of three larger cable reels in a box container



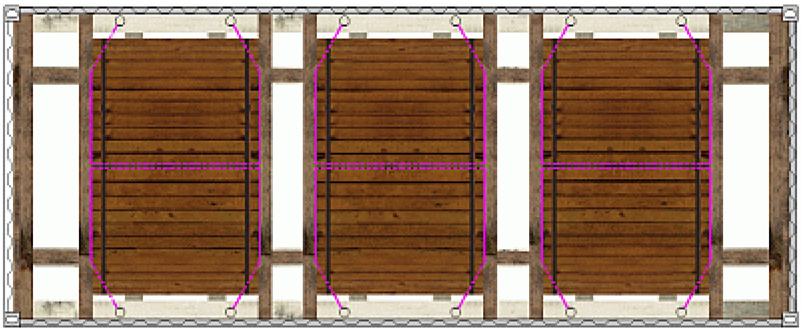
Load distribution and lateral securing of the cable reels

The cable reels are loaded uniformly in such a way that two lashing points are available on each side for each cable reel.



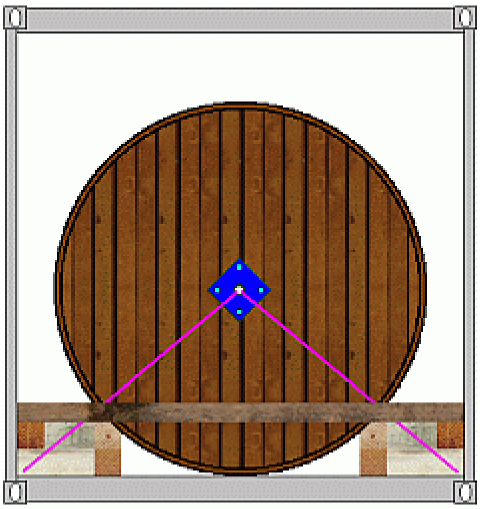
Lateral securing using wedge members and bracing

To achieve better lateral securing, the wedge members were raised by placing them on other lengthwise squared lumber. In the Figure, transverse securing is effected at the level of the wedge members. It is also the intention here to secure the cable reels additionally by loop lashings through the eye loop lashings through the eye. In the case of lashing points recessed into the floor, the outer crosspieces in the bottom layer must be so positioned that the lashing points remain accessible.



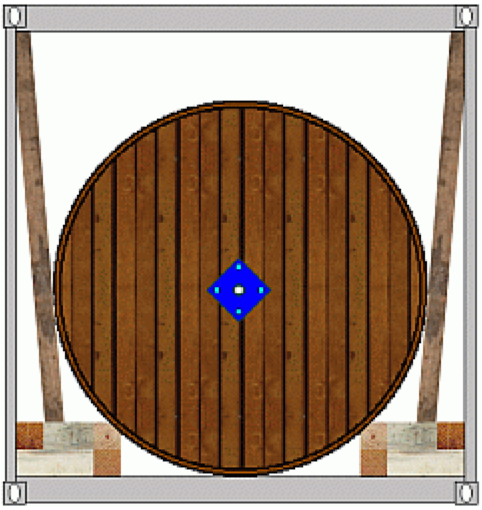
Lengthwise securing using bracing, crosswise and vertical securing by bracing and loop lashings through the eye

One loop lashing is positioned to the left and right through the eye of each cable reel. Together with the transversely acting wooden members, they secure the cable reels laterally and prevent them from popping out of the beds under dynamic loads. The cable reels are blocked in the lengthwise direction. At the same time, the loop lashings through the eye secure the cable reels against lengthwise tipping.



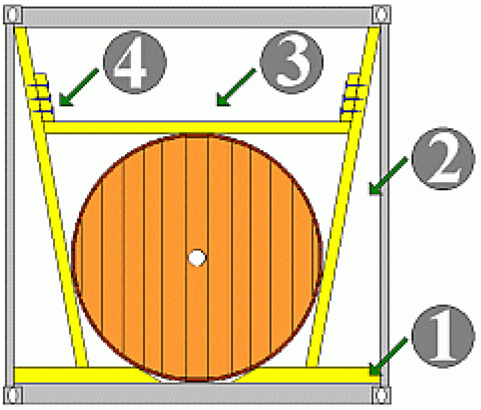
Securing by loop lashings and wooden bracing, in cross-section

If lashing points are absent, additional lateral securing may be achieved by simple shoring, which is fitted between the bed lumber and the top side rail in such a way that they are retained by the container corrugations.



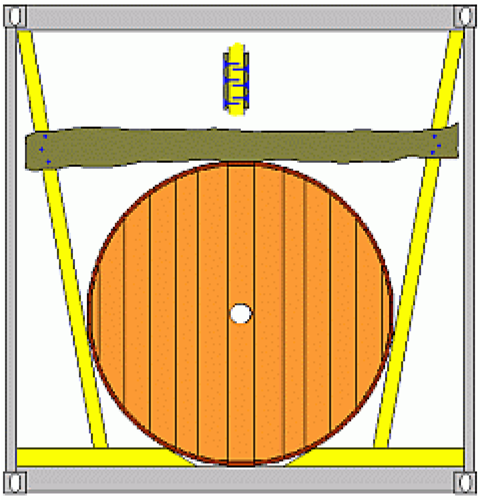
Additional lateral securing by shoring

If no suitable lashing points are available in a container, lateral securing may be achieved solely by shoring. To what extent the use of wedge members or even raised wedge members is necessary depends on the particular circumstances. A simple variant is presented below, in which all that is used in the floor area is beveled crosspieces.



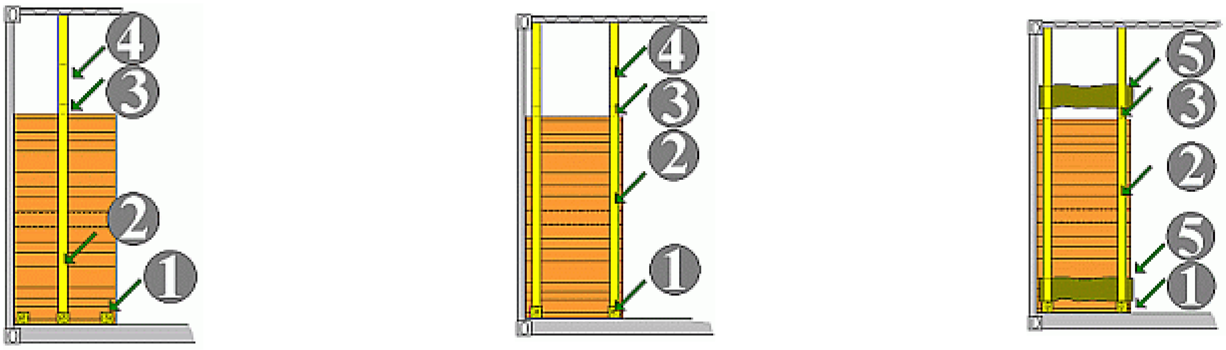
Lateral securing by shoring - cross-section

Each cable reel is secured in the floor area with the beveled squared lumber (1). The shoring (2) is fitted between bottom cross members and top side rails in such a way that it is stabilized by the container corrugations. Crosspieces (3) are fitted between the shoring and secured with cleats (4) in such a way that they rest on the reels.



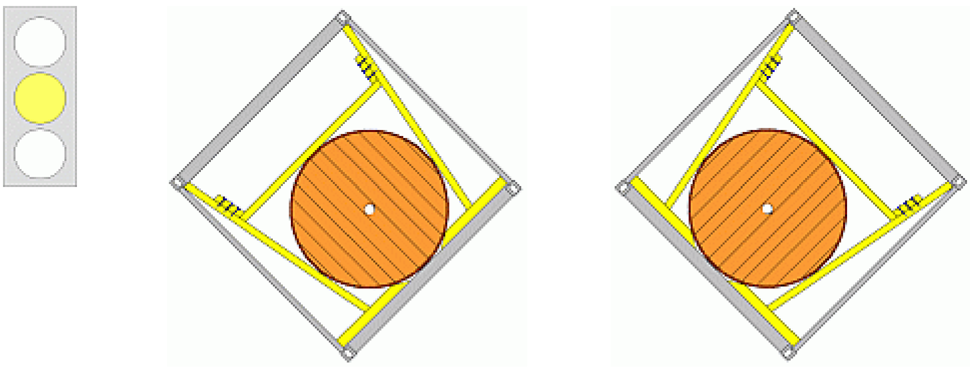
Vertical securing using boards - cross-section

Instead of squared lumber, vertical securing may also be provided by wooden dunnage boards nailed or screwed against the shoring from both sides.



Shoring variants - side view

It depends on the dimensions and weights of the cable reels whether one shoring structure or two is provided on each side per cable reel. Sometimes additional bracing with horizontal boards (5) or even boards nailed on diagonally is necessary, to provide the shoring with a secure hold.

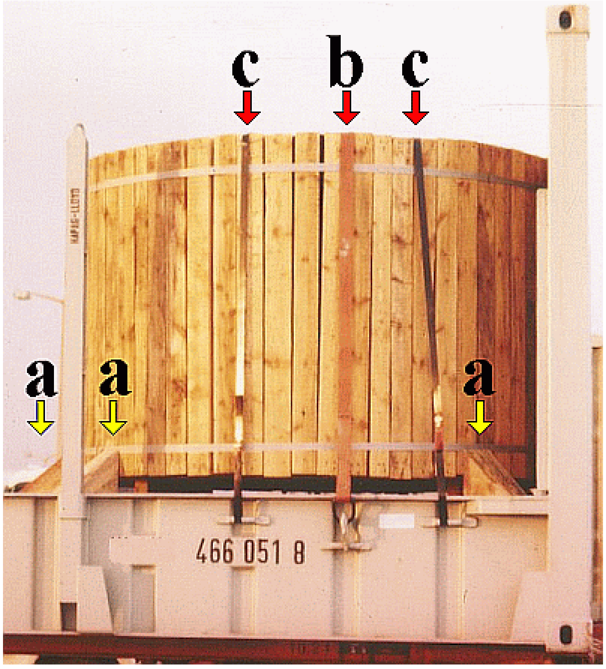


Cable reels at a tilt of 45°

However, the Figures shows clearly that it is more favorable to raise the wooden members in the floor area, since the weight-force vector is clearly outside the line of contact with the bottom cross members.

5.2.7.2 Cable reels on a flatrack, winding axis vertical

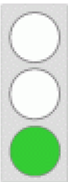
Inadequately secured cable reel

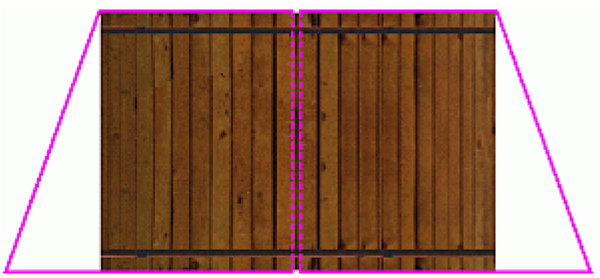


The wedges (a) have been correctly cut, namely in such a way that nails can be driven into the face grain. All in all, the small number of nails cannot apply sufficient shearing force to secure the cable reel with the wedges in the floor area. Additional measures would have been necessary.

The webbing belt (b) comes from a lashing reel fixed to the flatrack - it is tensioned on one side and is passed directly over the rough, sharp sawn edges of the reel boards without using edge protectors. There is a risk of fraying.

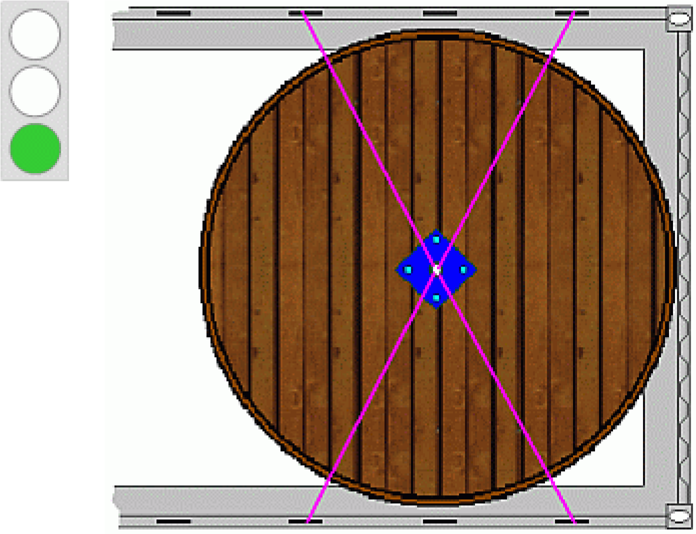
The two steel straps (c) have very low elasticity, roughly half of which has already been used up for pretensioning. Approx. 7.5 mm residual elasticity remains. The slightest jolt during transport would cause the steel strapping to cut into the wood and slacken. Since it is used as tie-down lashing, it can then no longer exert any securing force.





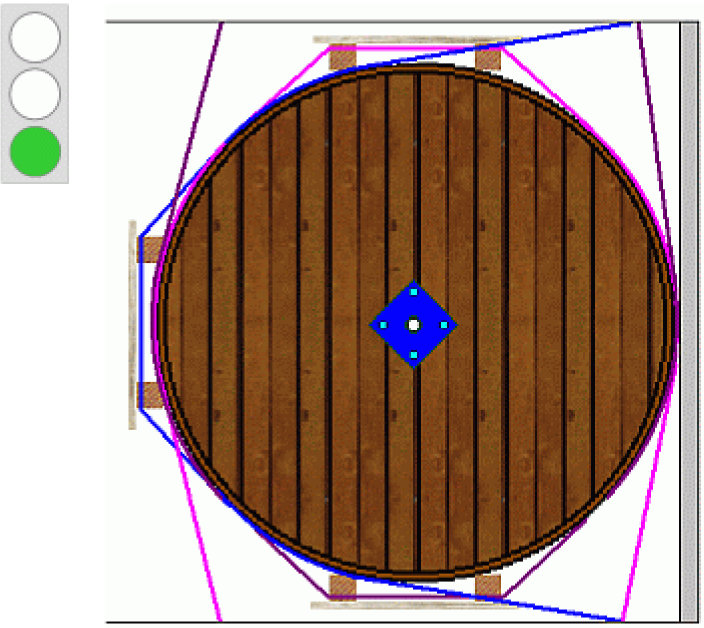
Loop lashings through the eye - diagonal section

The simplest option is to position the cable reel in such a way on squared lumber underlays that the eye and the path to the most favorable lashing points remain accessible, and then to secure it with four loop lashings through the eye.



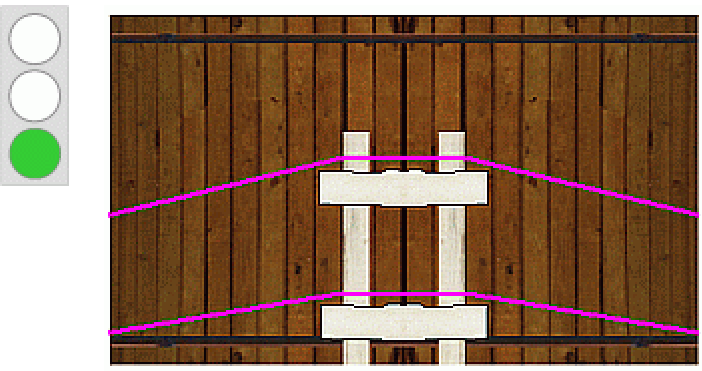
Loop lashings through the eye - plan view

If the eye is inaccessible or it is too difficult to pass lashing means through the eye, securing using obliquely applied loop lashings at the end wall and the two sides is possible.



Securing by loop lashings

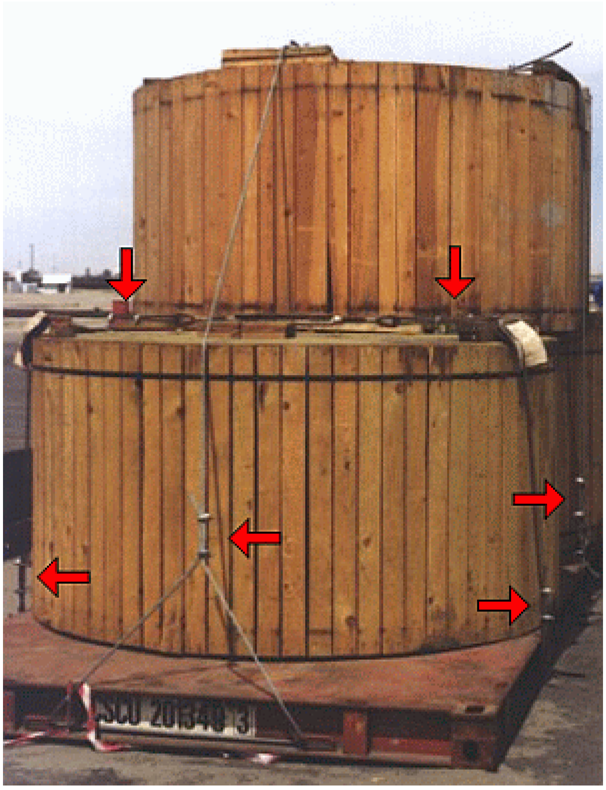
The blue loop lashings hold the reel firmly against the end wall and at the same time secure it on the left. The pink loop lashings secure it against movement to one side (upwards in the Figure) and the purple loop lashings secure it against movement to the other side (downwards in the Figure).

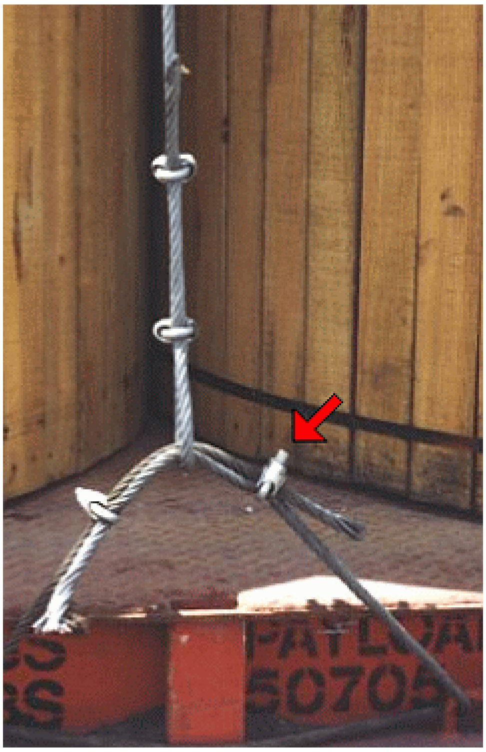


Notched squared lumber holds the loop lashings firm against slippage

The loop lashings may be held firm by notched squared lumber, which is made into a lattice using board ends and positioned in front of the reel. Whether additional securing against tipping has to be applied depends on the diameter:height ratio of the cable reel.

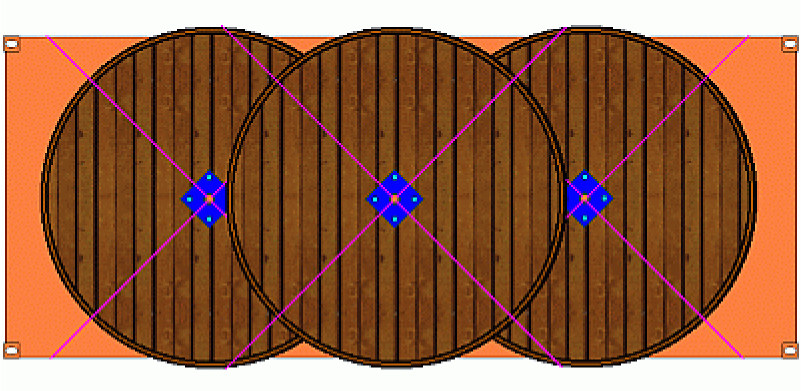
Three cable reels on a 20' platform





Inadequately secured cable reels on a platform

The cable reels cannot be held secure by the longitudinally and transversely tensioned tie-down lashings. Moreover, the wire rope lashings have been applied in nonuniform manner. Too few wire clips have been used and some of them have been applied contrary to the rules of application.

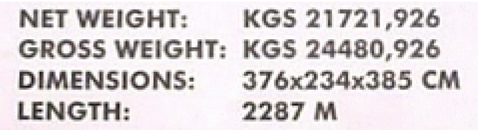
 

Cable reels each secured with four loop lashings through the eye

The cable reels can easily be secured with four loop lashings through the eye per reel. The number and orientation of the lumber members laid beneath and between the reels should be such that the cable reels are not subject to any harmful pressures and at the same time application of the lashing means is not prevented.

5.2.7.3 Overheight cable reels on a flatrack, winding axis horizontal and crosswise

Particularly heavy cable reels on 20' flatracks



NET WEIGHT:	KGS 21721,926
GROSS WEIGHT:	KGS 24480,926
DIMENSIONS:	376x234x385 CM
LENGTH:	2287 M

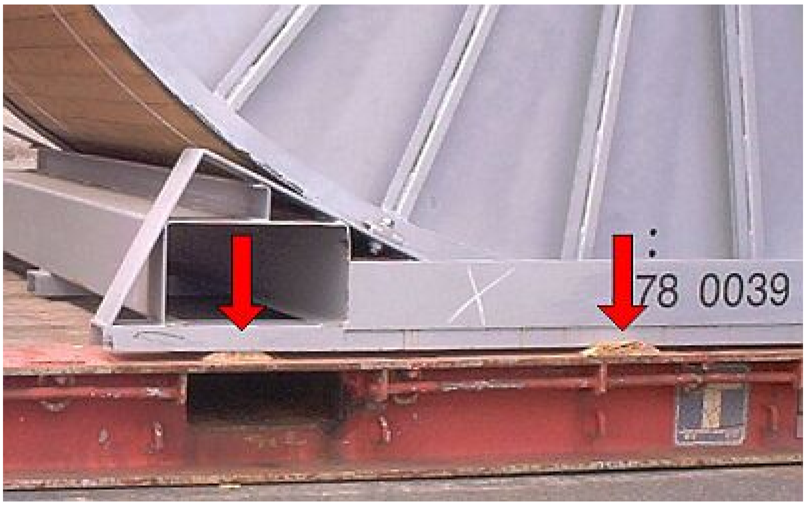
Some reel labeling details

For a voyage to Indonesia, these reels need particularly careful securing, since the probability that the ship will meet with bad weather increases with the length of the voyage.

Heavy, bulky cable reels on 20' flatracks

Poorly constructed floor assembly made from U-profiles

It was foolish of the manufacturer to choose a floor structure of three U-profiles extending perpendicularly to the reel axis. Its six steel strips provide so little surface area that laying friction-enhancing underlays is pointless.



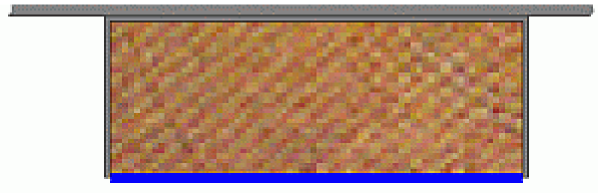
Squashing of the boards laid underneath due to excessively small bearing areas (selective enlargement below)


Floor structure and underlays cause extremely high pressures.

The boards laid underneath are squashed by the extremely high pressures. If four approx. 200 mm wide boards are laid underneath and the steel thickness of the 3 U-profiles is 8 mm, the bearing area is 24 x 200 mm x 8 mm = 38,400 mm² or 0.0384 m². With a cable reel gross weight of 24,481 kg or a normal force of 240,159 N, the pressures are 6,254,141 pascals, i.e. approx. 6.3 MPa. This would previously have been written as 637 metric tons/m².


Per transverse board, the load is distributed over six tiny strips.

It would have been better to omit the boards and to have laid the cable reel directly on the flatrack. However, friction is reduced markedly thereby, since at the outside steel is resting on steel. The use of strips of friction-enhancing mats is out of the question, since they would be cut and chafed in transit by the heavy load.



Floor structure with integral friction-enhancing material

The manufacturer of the cable reels or floor assemblies for them may assist in subsequent cargo securing by incorporating squared lumber and friction-enhancing material into the U-profiles.

Preparation of inadequate "securing means" from single-use webbing belts

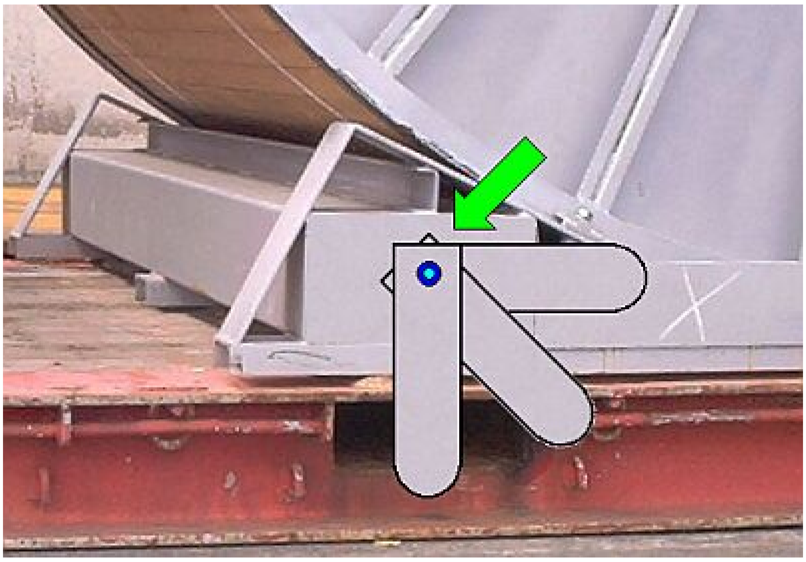
The initial securing stages illustrated here are wholly inadequate. On the one hand, webbing belts must be applied over a large area, which is impossible here; on the other hand, the chosen securing methods are not capable of holding the approx. 25 metric ton mass on the flatrack over an extended period.

Inadequate "securing" with single-use webbing belts

Even if it is assumed, incorrectly, that 3,000 daN of lashing force could be produced with a textile strap, the horizontal lengthwise securing force would amount to 1,500 daN in the longitudinal direction because of the lashing angle. The vertical component amounts to 2,100 daN. The method of application means that the cable reels are virtually unsecured in the transverse direction.

Lateral securing using steel edge provided at the design stage

The cable reel could be held absolutely securely on the flatrack if the manufacturer had given some thought to cargo securing from the outset. A steel edge which is welded on or can be bolted on ensures 100% secure lateral securing.



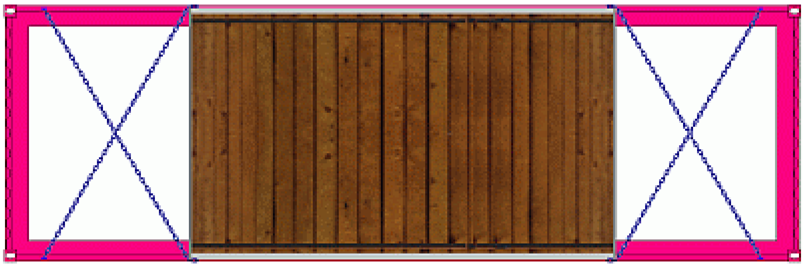
Lateral securing option using steel lugs

Steel lugs provided at the design stage, which may even be adjustable in the transverse direction, would be another possible way of ensuring transverse securing. A large number of other options is feasible - it is not unreasonable to expect the manufacturer's engineers and technicians to display a little imagination.

Lengthwise securing using squared lumber

Appropriate lengthwise cargo securing can be readily achieved by using squared lumber bracing.

Lengthwise and transverse securing using chains



Lengthwise and transverse securing using chains - plan view

The use of chains allows securing to be achieved in both the transverse and lengthwise directions. Because of the package dimensions and the lashing points provided, the transverse components turn out to be greater than the lengthwise components. To achieve adequate securing, several chains should be used or the longitudinal components should be supplemented by additional squared lumber bracing.

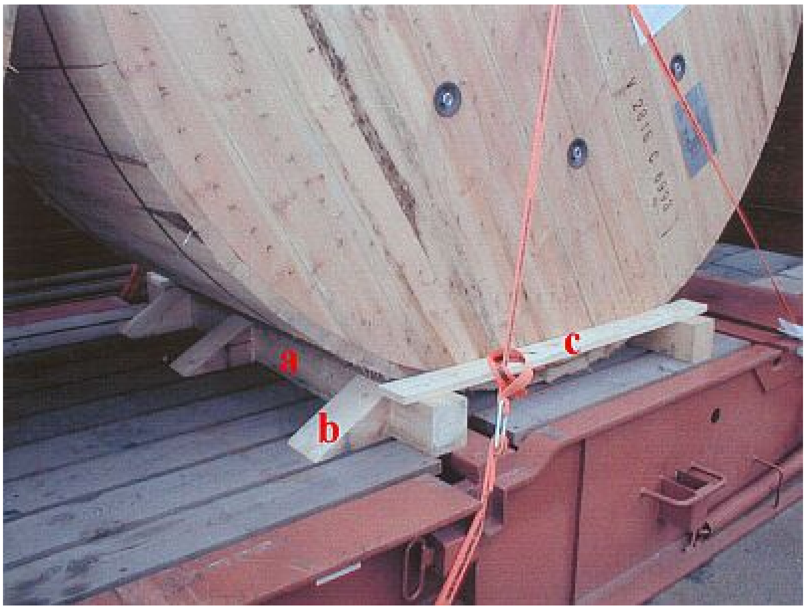
Vertical securing and securing against tipping using vertical and oblique lashings

Provided that the cable reel is secured adequately in the floor area against lengthwise and sideways shifting, vertically and obliquely applied lashing are sufficient to secure the cable reel against tipping and other vertical forces.

Cable reels on 40' flatracks

Inadequately secured cable reels on a 40' flatrack

The two outer reels are not stowed with a tight fit against the end walls of the flatrack. Lengthwise securing is achieved by the lashing belts passed through the eye. The effective horizontal component amounts to approx. 40% of the maximum securing load. In the case of lashing belts of 2,000 daN maximum securing load, each cable reel would be secured with 2 x 2,000 daN x 0.4 = 1,600 daN in each longitudinal direction. However, this theoretical value is not achieved, since the webbing belts are not used properly. The useful maximum securing loads cannot therefore be determined.

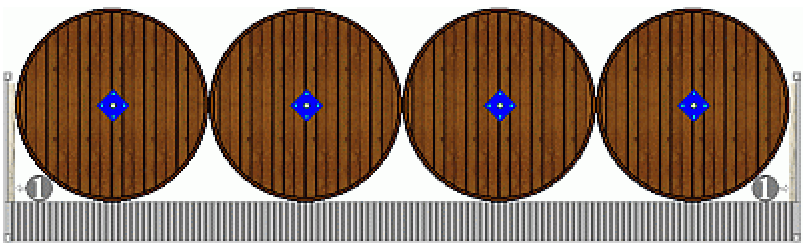


Detail of the floor area of a cable reel

The squared lumber (a) laid crosswise can only contribute to a small degree to lengthwise securing due to the incorrectly cut wedges (b. The wooden members (a) are only held together minimally by the nailed-on board (c). In addition, board (c) constitutes the only transverse securing, since the webbing belts only hold the cable reel by means of the vertical pretension component together with friction. The resultant values are minimal.

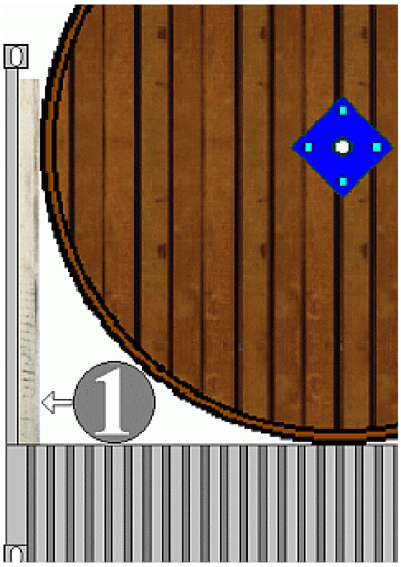
To sum up: cable reels cannot possibly be sent on a voyage like this. With the exception of ships with flaps, in which stowage is also possible in the bottom of the ship, flatracks will most probably be stowed in the top tier below deck or on deck.

In general, the following procedure can be followed for such cargoes:

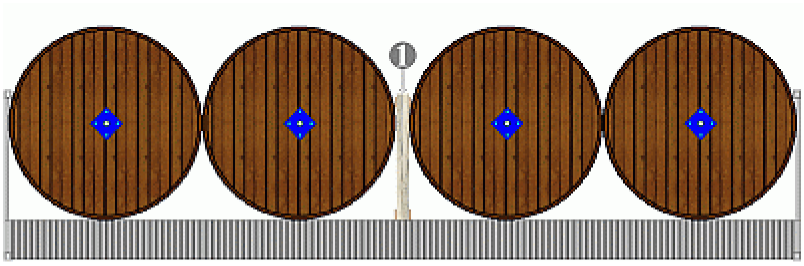


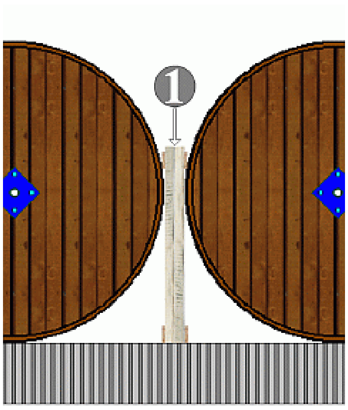
Above and selective enlargement to the right:

Compact stowage of relatively light cable reels: gaps filled at the end



The reels are loaded onto the flatrack. To prevent accidents, each reel should provisionally be prevented from rolling by wedges, beams or the like. If gaps are left at the front end wall, they should be filled with squared lumber, planks or boards (1). The bracing should be directed inwards from the external edge of the reels, so that the high strength of the outer panels of the reels is utilized.



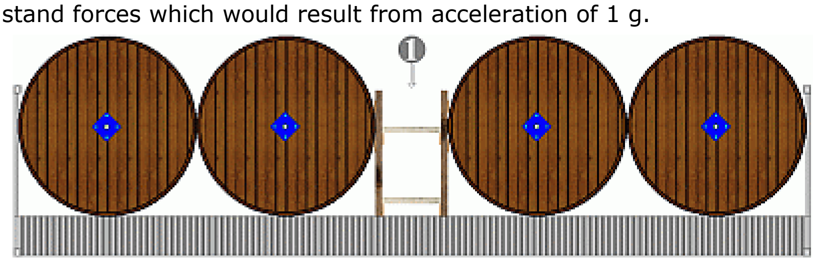


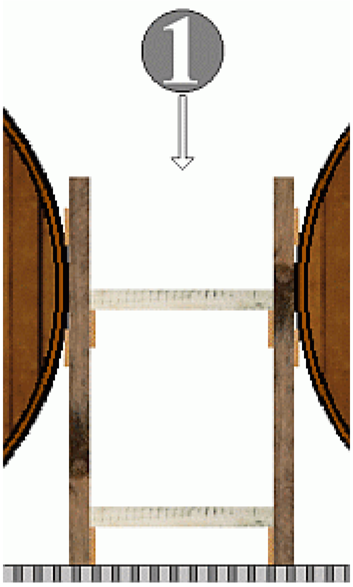
Above and selective enlargement to the left:

Compact stowage of relatively light cable reels: gaps in the middle

Loading from the ends to the middle is easier. To brace the gap remaining in the middle, only half the lumber cross-section is required, because only half the load is applied to the lumber (1). Care is required if, in the case of reels of the size shown in the end area, container handling could be obstructed.

In the case of a mass per cable reel of only 3,000 kg, i.e. 12,000 kg altogether, the end walls of the flatrack can still withstand forces which would result from acceleration of 1 g.



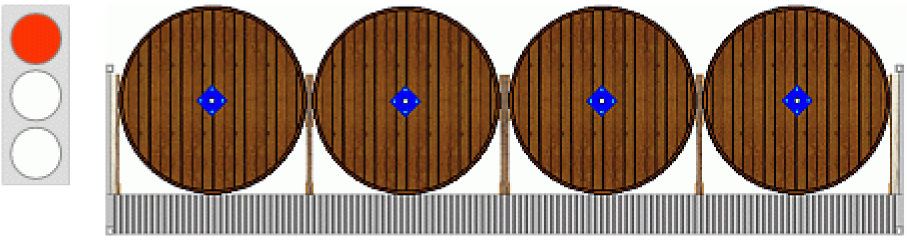


Above and selective enlargement to the left:

Packing variant - larger gaps in the middle

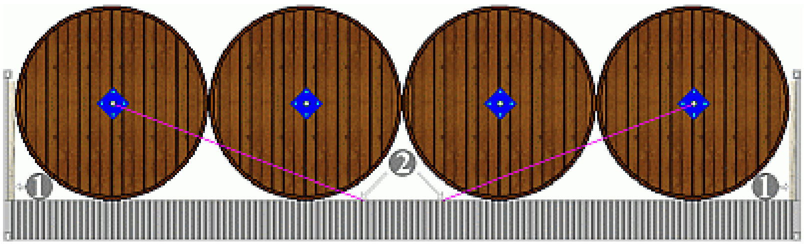
If larger gaps (1) remain, it is always better to leave these in the middle and brace them.

So that the wooden members are held secure, they should be connected together transversely by wooden boards. Attachment to the boarding of the cable reels requires the greatest of care, in order not to damage the cables.



Impractical: Leaving several gaps and bracing them

Since the end walls of the flatrack can be loaded with 0.4 times the payload, all that is needed to achieve adequate securing of a cargo of a total mass of up to 40% of the payload is compact stowage or filling of the gaps.



Relieving the load on the end walls by lashings

If the mass of the cable reels to be stowed exceeds this value, the load on the end walls of the flatrack must be relieved by inwardly tensioned lashings (2). Loop lashings passed through the eye and pulled towards the middle of the flatrack are best suited to this task. Number and type and thickness of material depend on the maximum securing loads of the lashing points on the flatrack and the values of the acceleration to be taken as basis for the particular transport. When calculating corresponding numerical values, coefficients of sliding friction must not be taken into consideration, since the cable reels can roll when stowed in the ways shown so far.

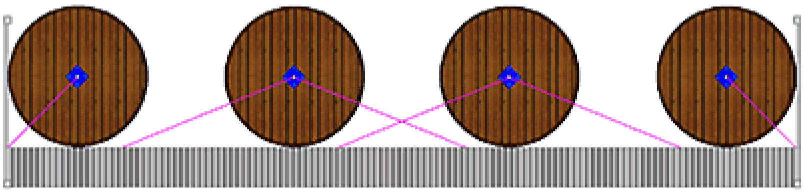
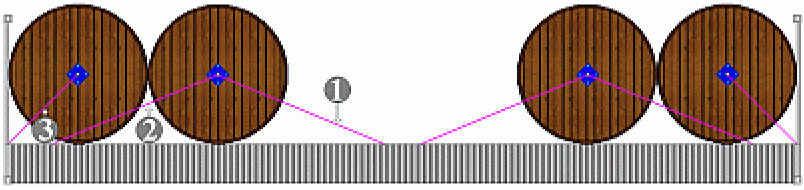


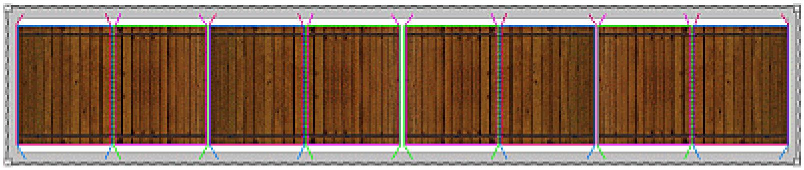
Diagram showing the principle of individual lengthwise cable reel securing

If the total mass of the cable reels reaches the payload of a flatrack, load distribution could look like this in the case of uniform stowage. However, the disadvantage is that only some of the end wall strength is utilized. If each reel exhibits 25% of the payload mass, while the end walls can be loaded with 40% of the payload, 15% of the strength is wasted. If, as is shown here deliberately, the lashing angles differ, the maximum securing loads of the lashings would likewise have to be different.



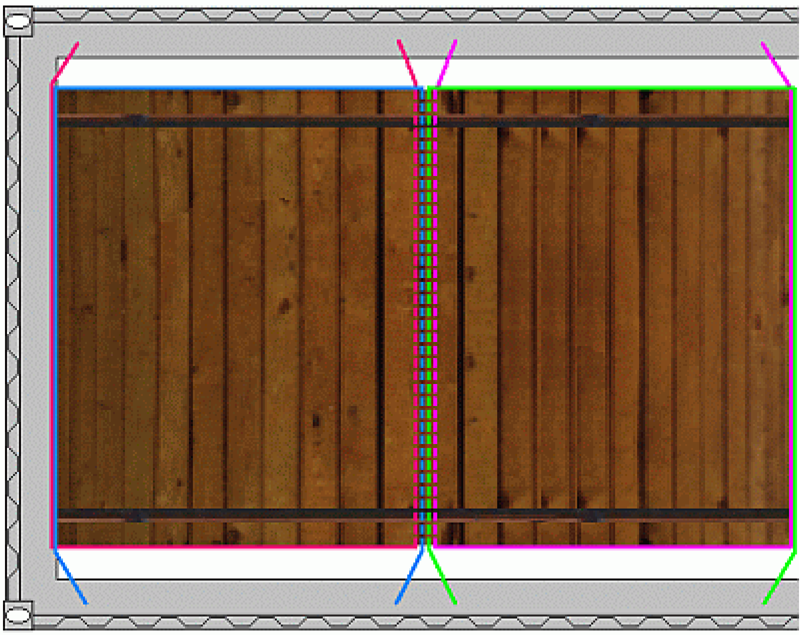
Variant of individual lengthwise securing

If the mass of the cable reels reaches the payload of the flatrack, and longitudinal accelerations of 1 g are assumed, the stowage method illustrated is particularly favorable from the point of view of cargo securing. Since 50% of the payload has been packed against each end wall, but the end wall themselves can only bear 40%, the lashings (1) have only to take up forces produced by 10% of the cargo mass and the 1 g acceleration. However, the lashings (2) and (3) have to be so strong that their effective force components correspond to the forces resulting if the mass of a cable reel is multiplied by the assumed acceleration.



Lateral securing using loop lashings through the eye

Provided that stanchions are not provided for bracing purposes, lateral securing of cable reels may be ensured by loop lashings through the eye.



Loop lashings through the eye of a cable reel

The red and purple loop lashings secure each cable reel against movement to one side while the green and blue secure against movement to the other side. To calculate the necessary maximum securing loads, the corresponding coefficients of sliding friction can here be taken into consideration. Using friction-enhancing materials under the reels can have a considerable effect on the material thicknesses required.

It should be noted that loop lashings through the eye produce almost no lengthwise securing forces.

N.B. In the case of cable reels which are stowed with their axis lying horizontally, it is essential to check that the container's admissible line loads are not exceeded and that no excessive point loads arise.

5.2.8 Cases and crates

5.2.8.1 Overwidth boxes and crates, example 1

Three flat cases on a 20' flatrack

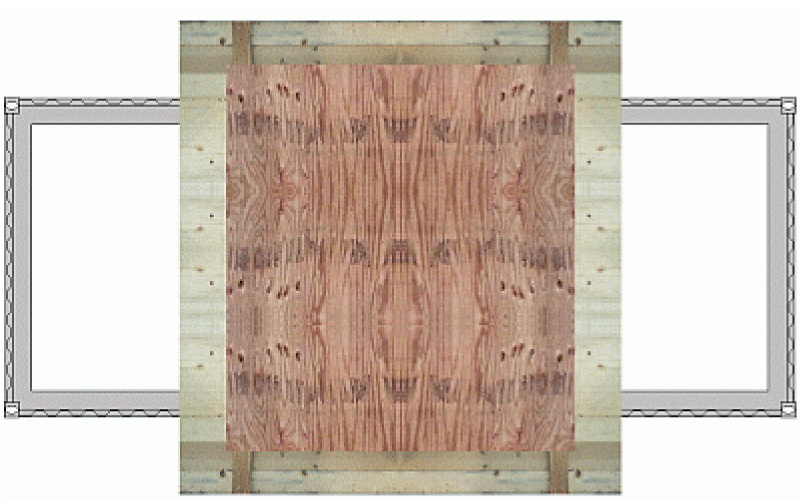
It is impossible to secure laterally overhanging cases with tie-down lashings, since the cases can move freely to and fro in the tie-down lashings (1). Lengthwise securing with nailed-down lumber (2) is worse than useless and cannot prevent shifting in the longitudinal direction; indeed, not only that, but nails hammered into the outside of the cases may damage the goods. The nailed-down wedges (3) are not capable of providing adequate securing against shifting, either. To sum up: Labor and material have been wasted, to no avail.

Inadequately secured cases on a 20' flatrack

Tie-down lashings cannot prevent shifting in the case of overwidth cases

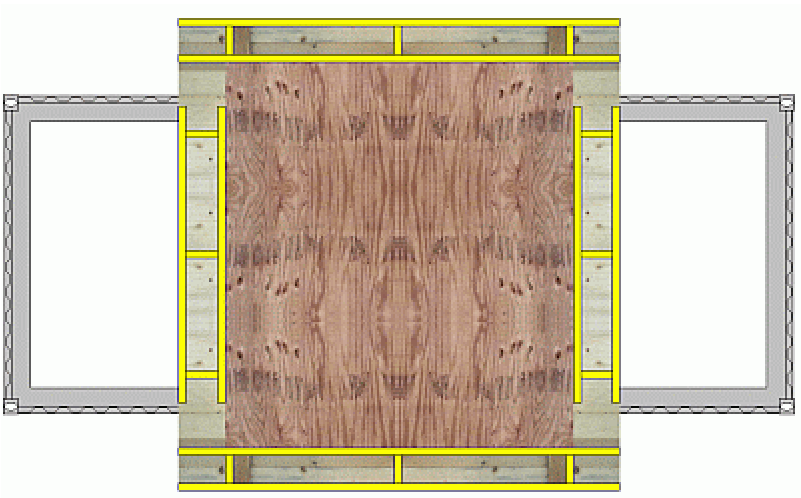
The following procedure could have been followed, to achieve optimum stowage and securing:

Step 1: Central loading of large overwidth box



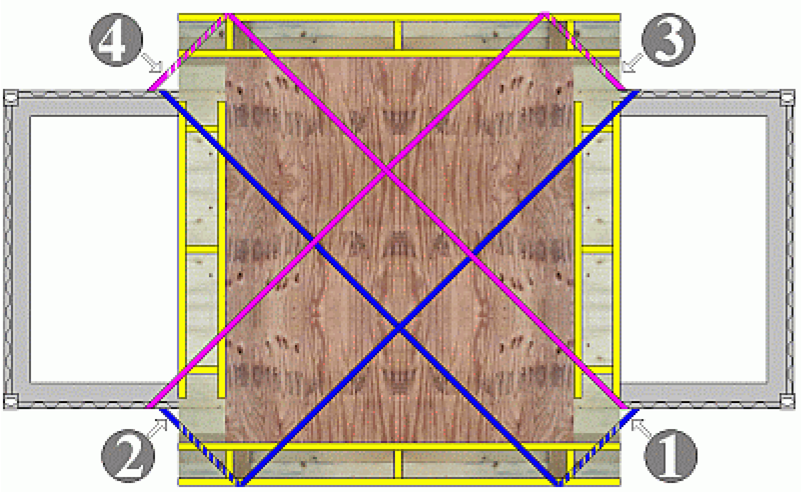
Step 2: Central loading of flat, shorter overwidth case

The shorter, flat overwidth case is loaded as second package. So that it is not damaged by the case to be loaded thereafter, on the one hand, but can be secured jointly with the case loaded first, on the other hand, a wooden frame is built around the case, the height of which matches that of the flat case.



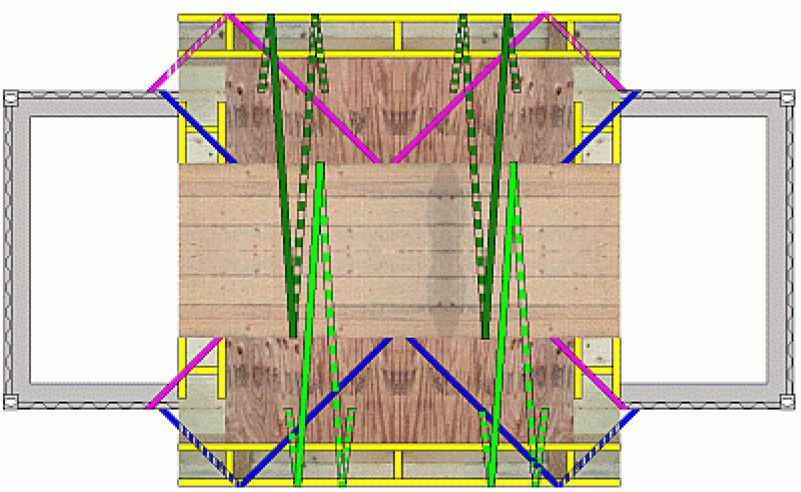
Step 3: Building a wooden frame round the flat case

Before loading can continue, these two cases are secured against sideways shifting with "true loop lashings" (half loops). The blue loop lashings (1) and (2) secure the cases on one side, the purple loop lashings (3) and (4) on the other.



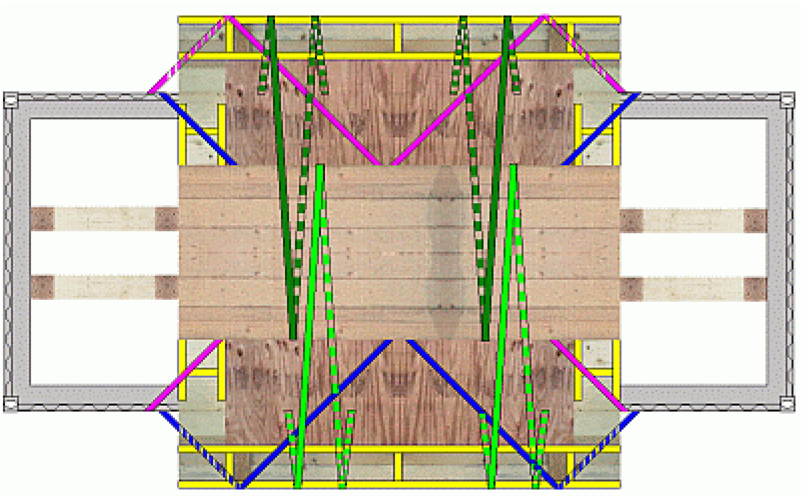
Step 4: Lateral securing of the overwidth cases using loop lashings

The narrow case is placed centrally on the two laterally secured overwidth cases and secured against lateral shifting by two loop lashings on each side. These "half loops" are light green and dark green in the Figure.

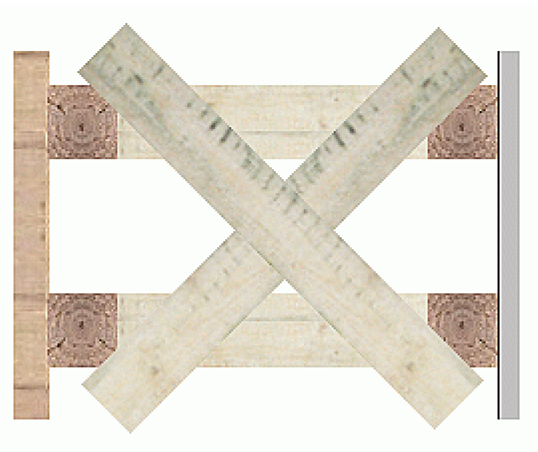


Step 5: Loading and subsequent lateral securing of the large, narrow case by two loop lashings on each side

The cases are secured jointly against the end walls of the flatrack using wooden bracing, which consists in each case of two "uprights" at the case sides and end walls with bracing fitted in between.



Step 6: Lengthwise securing of the cases using squared lumber bracing

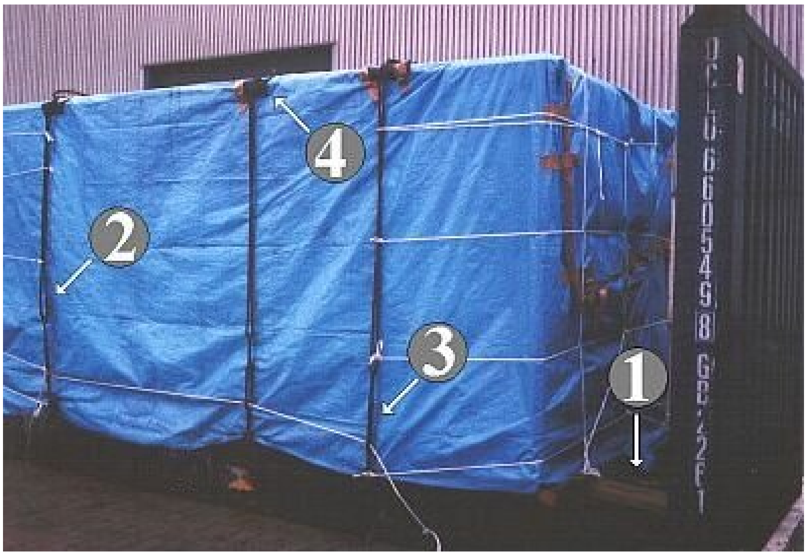


Step 7: Securing of the squared lumber bracing with wooden X-bracing, if there is concern that the wooden bracing members may become dislodged

N.B. So as to be able to work as quickly and efficiently as possible, the loop lashings are each attached at one end to the corresponding lashing points before loading.

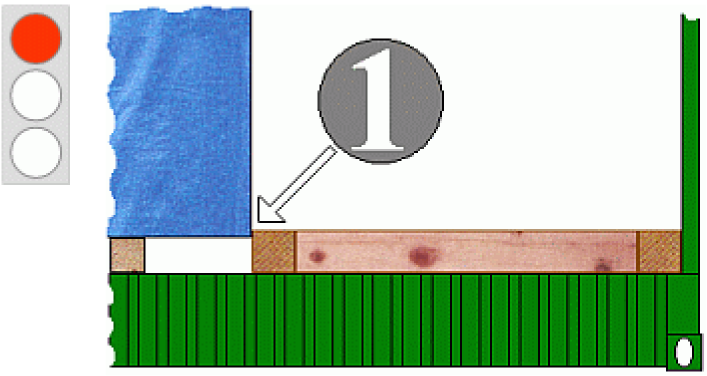
5.2.8.2 Overwidth boxes and crates, example 2

Case on a 20' flatrack



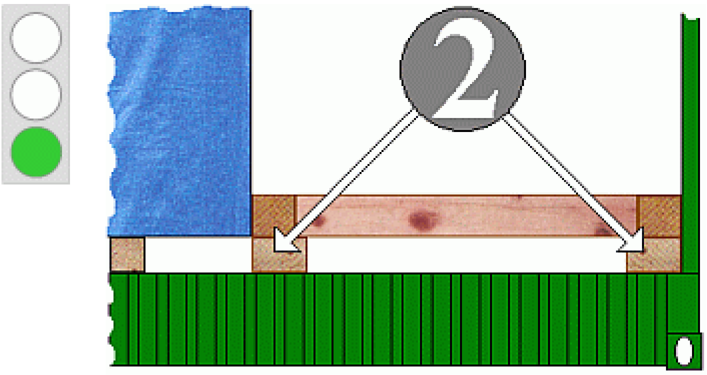
The wooden bracing at (1) consists of two lengthwise and crosswise beams, attached directly to the floor of the flatrack. Since the case itself is standing on transverse skids, the effective height of the bracing lumber is too small at the case end wall. It is uneconomic to secure the case by means of tie-down lashings of 16 mm diameter steel wire ropes and turnbuckles (2) and (3). It is a good idea to use edge protectors made from hard-wearing segments of automobile tires (4) and the weather protection with which the case is provided is definitely a positive feature. However, a few more meters of binder twine would not have done any harm. The adhesive strips used are water-resistant.

The small effective height of the squared lumber is shown here.

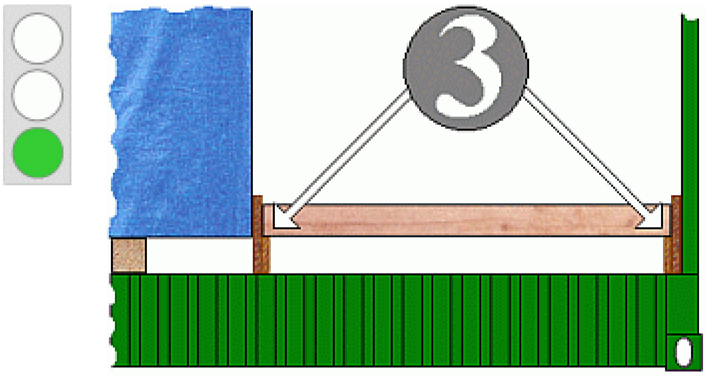


Inadequate effective bracing height

The problem could have been eliminated by using two more crosspieces (2).

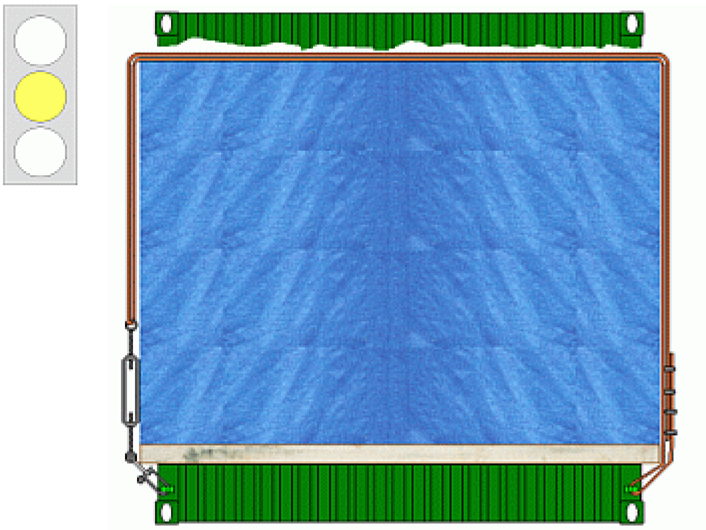


It would have been somewhat cheaper to use two boards (3) nailed together to form steps, between which the two lengthwise pieces are inserted.



It is a waste of material to use tie-down lashings made from steel wire ropes with a diameter of 16 mm together with turnbuckles, since, on the one hand, the maximum securing load of these materials is higher than that of the lashing points and on the other hand the method of arranging them requires an unnecessarily large amount of wire.

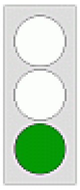
With normal deflection radii, 16 mm diameter steel wire ropes could be used to produce lashings with a maximum securing load of 10,240 daN. However, the lashing points on the flatrack have a maximum securing load of only 3,000 daN. Approx. 12 m of steel wire rope, two shackles, one turnbuckle and four wire clips are used per tie-down lashing.

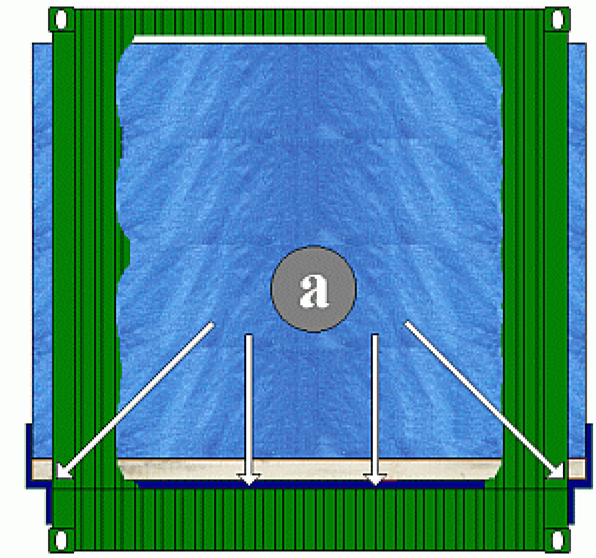


Basic diagram showing wasteful tie-down lashing

Another disadvantage is that, when the case is secured, all the tensioning elements are located on one side and the pretension is thus considerably higher on that side than on the opposite side.

Since the flatrack does not have stanchion pockets, it is out of the question to use specially shaped stanchions for transverse securing. From the point of view of labor and materials, it would have paid off to prepare "case restraint shoes" for transverse securing purposes.

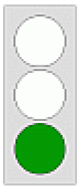


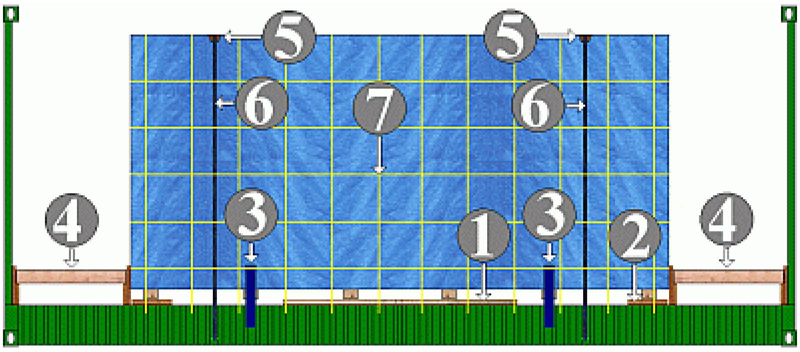


Lateral securing using case restraint shoes

With two such case restraint shoes (a), a 100% tight fit could have been produced for lateral securing.

Efficient securing could have been produced in this way:





Securing the overwidth case on a 20' flatrack

Boards of the same thickness as the case restraint shoes are positioned lengthwise (1) or crosswise (2) beneath the transverse members of the case bottom in such a way that the case cannot sag at the bottom. Two case restraint shoes (3) are positioned in such a way that the case can be placed on them with two of the transverse skids. The gaps remaining relative to the front end wall of the flatrack are braced with boards or planks and squared lumber (4). Edge protectors of a material with good recovery (5) are put in place and two steel strapping tie-down lashings (6) are fitted. The tarpaulin provided to protect the case from the weather is fixed securely with tightened and knotted close-meshed binder twine or the like, such as 4 mm thick PE or PP tape.

5.2.8.3 Overheight cases on flatracks, example 1

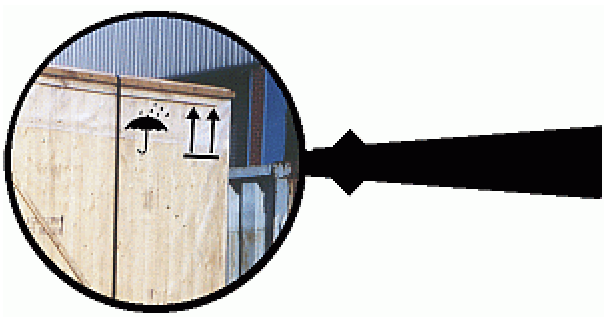
1,600 kg wooden case on a 20' flatrack

Overheight moisture-sensitive case on a 20' flatrack

The features of this stowed case which are immediately noticeable are the "Top" marking and the umbrella symbol. It would be desirable for this case to have been provided with the standard "Keep upright" symbol, in other words two upright arrows which are positioned at the top right and on an adjacent surface of the case, together with the umbrella symbol for "Keep dry".

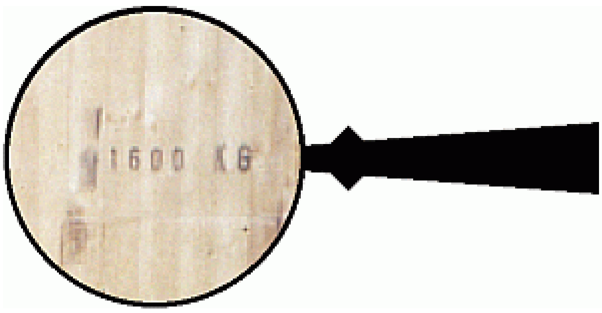
It is unlikely that the 0.2 mm thick (200 µ) film membrane additionally applied to the box would be enough to keep it dry for the entire voyage. Because of its overheight, the flatrack is best transported on board ship in a stowage space in the top tier below deck. However, it is more likely that the flatrack will be stowed on deck. It is unlikely that the film will be able to withstand the full rigors of a voyage, or indeed of onward carriage by railroad or truck.

Only passing mention will be made of the fact that the marking complies only in part with the standards; however, each of these shortcomings is relevant in the broadest sense to "cargo safety".



Sensibly and correctly affixed handling symbols

According to its markings, the case has a gross weight of 1,600 kg.



Gross weight of the case

The securing forces required according to the CTU packing guidelines are relatively simple to calculate, although the coefficient of sliding friction is incalculable. Because it is probable that the case will be loaded on deck or will be uncovered during onward transport, occasional precipitation must also be anticipated. Therefore, a coefficient of sliding friction of μ = 0.2 is assumed for the example, i.e. a friction value of 20% is used for calculation purposes. All numerical values are stated in decanewtons (daN).

The securing forces required for a voyage during which the flatrack is stowed "fore and aft" (fore and aft stowage) are calculated as follows:

Normal force of the package	Acceleration forces in		Friction forces, where coefficient of sliding friction μ = 0.2	Required securing forces	
	Lengthwise at 0.4 g	Crosswise at 0.8 g		Lengthwise	Crosswise
1,600	**640**	**1,280**	**320**	**320**	**960**

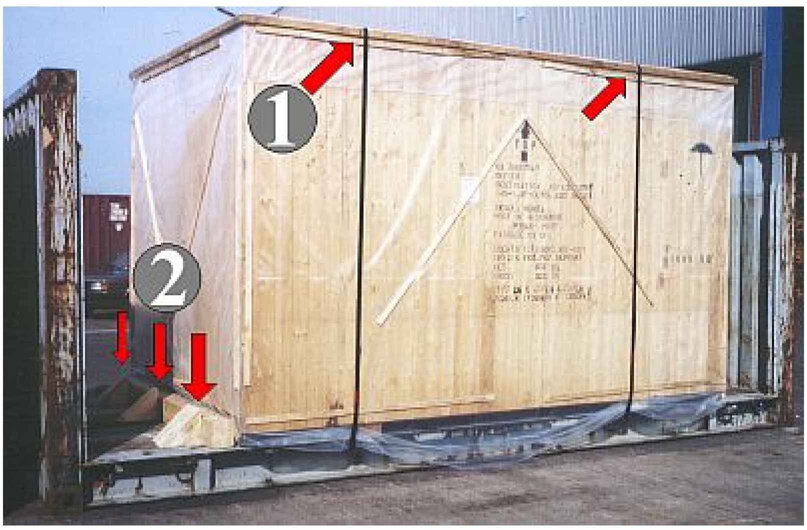
In the unlikely event of the flatrack being stowed athwartships on board ship, the following securing forces would be required:

Normal force of the package	Acceleration forces in		Friction forces, where coefficient of sliding friction μ = 0.2	Required securing forces	
	Lengthwise at 0.8 g	Crosswise at 0.4 g		Lengthwise	Crosswise
1,600	**1,280**	**640**	**320**	**960**	**320**

The case will probably be taken off the flatrack at the port of destination and carried onwards conventionally. However, to be on the safe side, it should be assumed that the case remains on the flatrack for onward carriage. It is not known how the flatrack would be positioned on a truck for road transport, but for rail transport it is assumed that no switching stresses arise. Under these conditions, the securing forces would be calculated as follows:

Normal force of the package	Acceleration forces in		Friction forces, where coefficient of sliding friction μ = 0.2	Required securing forces	
	Lengthwise at 1.0 g	Crosswise at 0.5 g		Lengthwise	Crosswise
1,600	**1,600**	**800**	**320**	**1,280**	**480**

With the selected securing method using tie-down lashings (friction loops) (numeral 1 in the Figure), the stowage direction of the flatrack is irrelevant, since tie-down lashings act in all directions. For the assumed coefficient of sliding friction of μ=0.2 and required securing forces of 960 daN for example, a total pretension of 4,800 daN would be necessary for the voyage (960 daN × 0.2 = 4,800 daN). If two tie-down lashings are present, each would have to be pretensioned to 2,400 daN and be capable of retaining this pretension through the voyage. In the example illustrated, steel strapping was used for the tie-down lashings, and was tensioned only over the top edges of the case. Even if it cuts into the lumber by only a few millimeters as the result of a jolt during transport, all pretension would be lost and the tie-down lashings would no longer have any securing effect on the case.

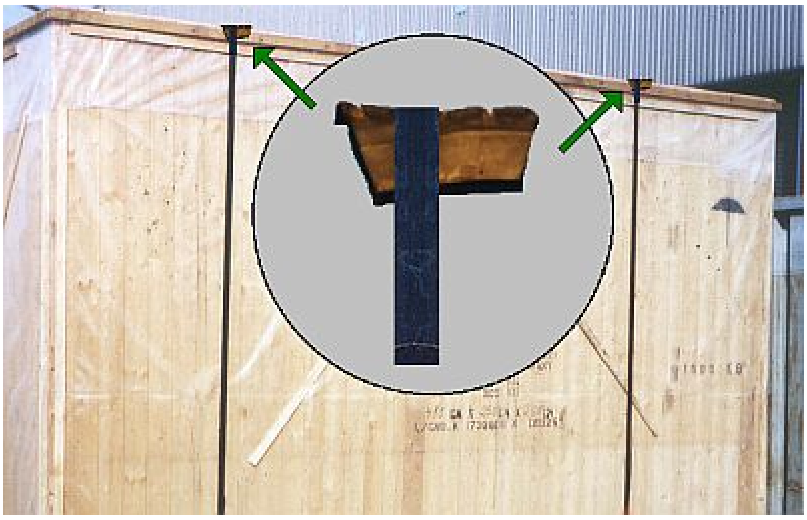


Shortcomings in case securing

The cohesive resistance of the nails in the wedges used for cargo securing (numeral 2 in the Figure) should be estimated at approx. 100 daN per nail due to the small plank thickness of the flatrack floor and the resultant low penetration depth. If there are three retaining nails hammered in vertically per wedge, the lengthwise securing forces produced by the three wedges amount to 900 daN. If the effect of the tie-down lashings is ignored, there is a slight cargo securing deficit.

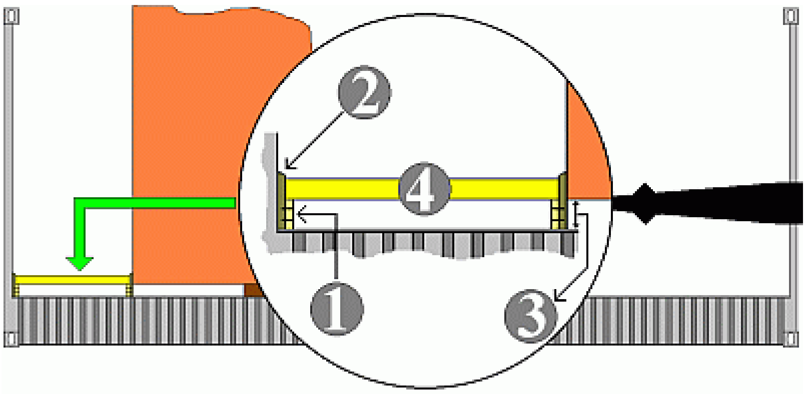
Given the low case mass of 1,600 kg, steel strapping tie-down lashings can also be used if it is ensured that the calculated pretension can be maintained throughout the voyage.

This may be ensured by combining the steel strapping with a material with good recovery. The use of automobile tire segments provides an economic solution.



Tire segment for improving elasticity and maintaining pretension

If it is assumed that the tools and lashing points used allow at most 1,500 daN of pretension per tie-down lashing, a securing force of around 300 daN may be achieved per tie-down lashing for a coefficient of sliding friction of 0.2. It is accordingly possible to achieve the securing forces required for maritime transport with four steel strapping tie-down lashings, while the forces required for onward carriage by road or rail would be covered with five.

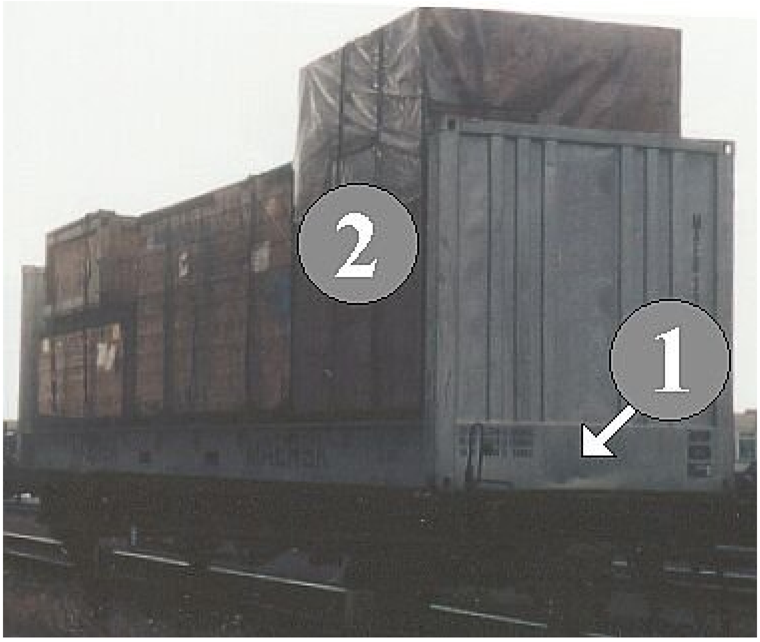


Producing simple bracing from wooden boards and squared lumber beams

In general, securing with wedges should be avoided with cases. If a tight fit is required in the lengthwise direction, much can be achieved with wooden bracing. For a case with a low mass of 1,600 kg, such wooden bracing is simple and cheap to produce. One narrow (1) and one wide board (2) are nailed together in each case in such a way that a step-shaped double board is obtained. The height of the narrow board must match the height of the case props (3). Bracing made from simple beams (4) is fitted - cheap 6 cm x 8 cm softwood is quite sufficient.

5.2.8.4 Overheight cases on flatracks, example 2

Various wooden cases, including one overheight case, on a 20' flatrack



Cases on a 40' flatrack on an Lgjs container car

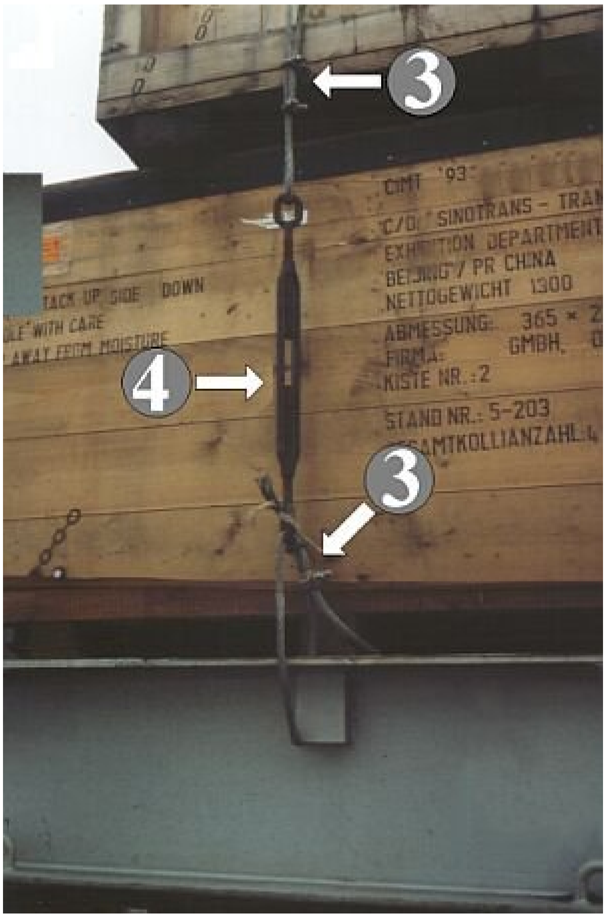
The end of the flatrack shows signs of rough treatment (1) - perhaps, in contravention of the rules, a forklift truck was used for switching. The case (2) is unfavorably positioned. All the cases are secured with tie-down lashings.

In the pictures, all the cases have been shifted somewhat to the other side, which would have made it possible to use stanchions on the flatrack.

The use of stanchions would have improved cargo securing.

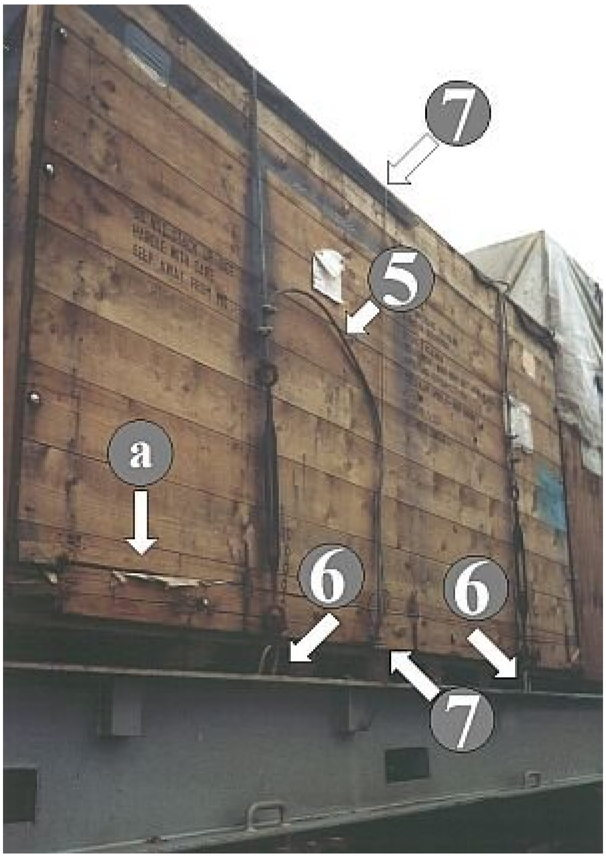
Other cargo securing options would also have been feasible:

Restowed case with additional direct spring lashings



Nonuniform securing wastes materials

Tie-down lashing made from 16 mm diameter steel wire rope, together with two wire clips (3) and sharp edges, does not come anywhere near to achieving the maximum securing load of the turnbuckle (4) used. For cost reasons, uniform securing is essential.

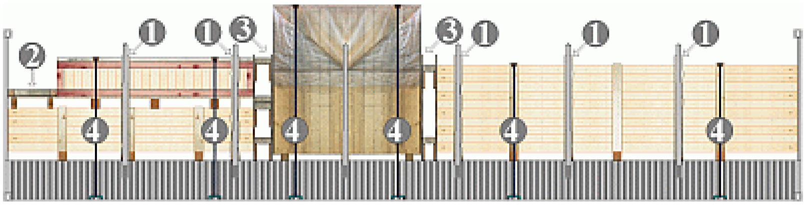


Nonuniform securing wastes materials

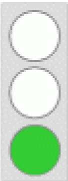
Even at the port of departure, the first packaging deficiencies are visible at (a) - the statement made above about using two wire clips, the turnbuckles and nonuniformity applies. The wire rope end (5) which is hanging loose constitutes both a waste of materials and an accident risk. With a maximum securing load of 3,000 daN, the lashing points at (6) ought to be fully utilized, and, if the thin wire (7) had been used correctly and sensibly, uniform securing could have been produced. However, here the wire was passed round sharp edges and fastened with one wire clip.

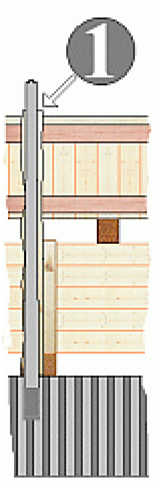
Unbraced gaps in the load are a securing risk.

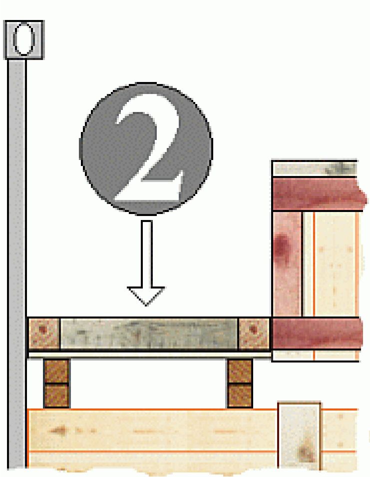
The cargo has been loaded in such a way that the overheight case can be positioned so that it is held precisely centrally by a stanchion. The long case rests against the right-hand end wall, the mid-length one against the left-hand end wall. The smallest case is positioned on the mid-length one, but is packed flush with the inner end wall thereof.

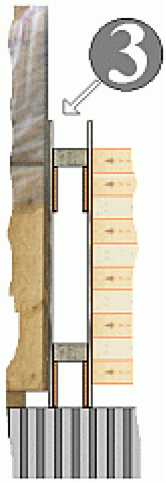


Securing a number of cases on a 40' flatrack









Details of gap bracing

The smaller gaps between stanchions and the outsides of cases are filled with boards (1). The gaps between the overheight case and the adjacent cases are braced by means of a structure consisting of wooden lattices, i.e. boards nailed together vertically and transversely, and squared lumber ends (3). The gap between the end wall and the small case packed on the top contains squared lumber bracing (2). Since the end walls and stanchions provide a tight fit in the horizontal directions, supplementary securing comprising two steel strapping tie-down lashings (4) per case or case stack can now readily be provided. Segments of automobile tires are used as edge protectors.

Leaving gaps at the end walls would not save any labor or material. The advantage of the load distribution chosen is that the overheight case could be readily provided with additional securing means if the individual stanchion proved insufficient. Lateral securing with direct lashings would then be feasible, together with spring lashings.

5.2.8.5 Overheight cases on flatracks, example 3

Two overheight wooden cases on a 20' flatrack

Inadequately secured cases

The two cases are "secured" in the floor area by wooden members nailed in front of them, or "wooden fixings", only the shearing forces of the nails being capable of furnishing any resistance against shifting.

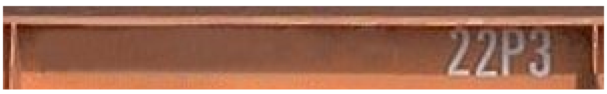
Inadequate securing with wooden fixings

The cases are more than three times as tall as they are wide, so, given their small standing area, they are at any rate to be classified as at risk of tipping. Two tie-down lashings per case are not enough to make them safe.

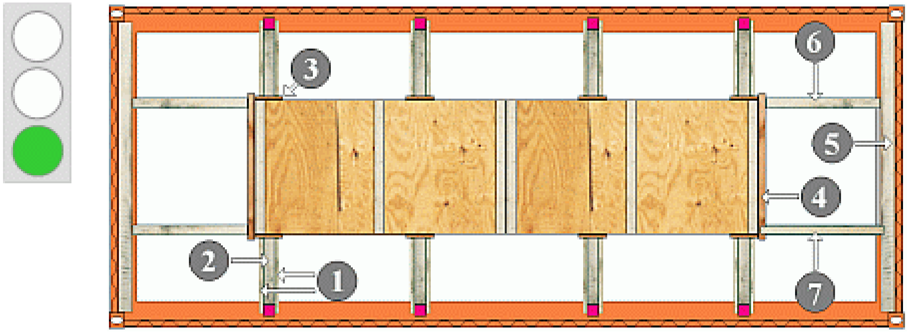
Two tie-down lashings per case cannot prevent them from tipping.

This is particularly obvious if the flatrack is inclined sideways by 30°.

Case at risk of tipping, inclined by 30°

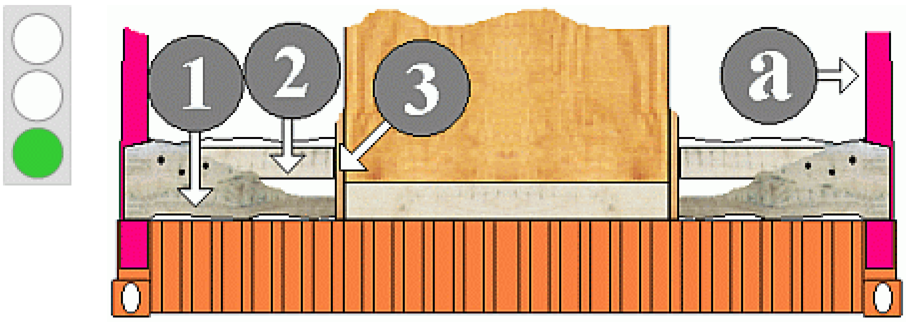


The container type 22P3 used has four stanchions on each side, each with a loading capacity of 2,000 daN. Relatively low mass cases are therefore easy to secure.



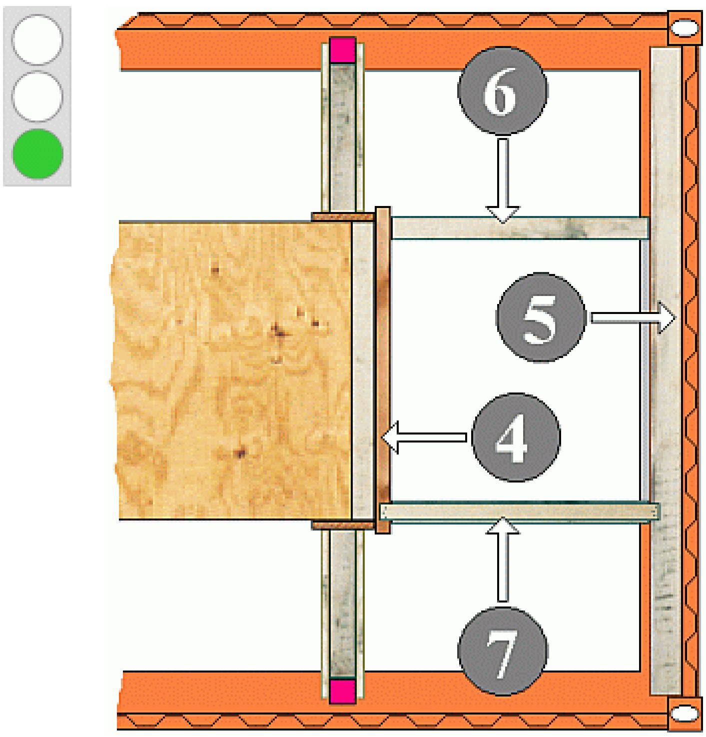
Cases secured in the floor area against stanchions and flatrack end walls

A total of eight struts are built each from two boards (1) and one squared lumber member (2) and are placed between the stanchions and the boards (3) positioned in front of the cases.



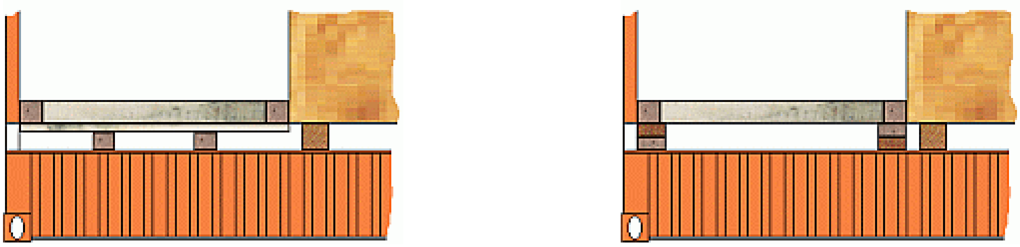
Securing the cases transversely - end-on view - details

Reasonably priced, unsquared boards can be used as the transverse (1) and vertical boards (3), while the sizes of the transverse braces (2) should be matched to the stanchions (4) from the point of view of width. Their height depends on the masses to be braced.

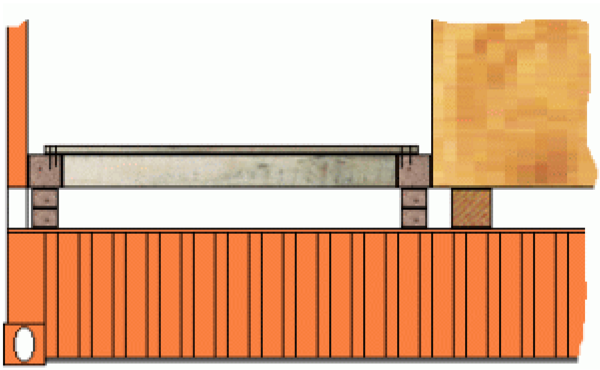


Securing the cases longitudinally - plan view - details

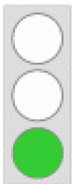
At each end of the cases, a squared lumber member or a beam (4) is firred in such a way that it lies horizontally at the level of the sufficiently strong case bottom. A squared lumber member (5) is raised in such a way at the ends of the flatrack that it is at the same height as the squared lumber member (4). These squared lumber members serve to distribute pressure to the flatrack end walls. Other squared lumber members are fitted precisely between the squared lumber members or beams (4) and (5) in parallel with the longitudinal sides of the cases. These members may either be built up from the bottom (6) or suspended on boards nailed over them (7).

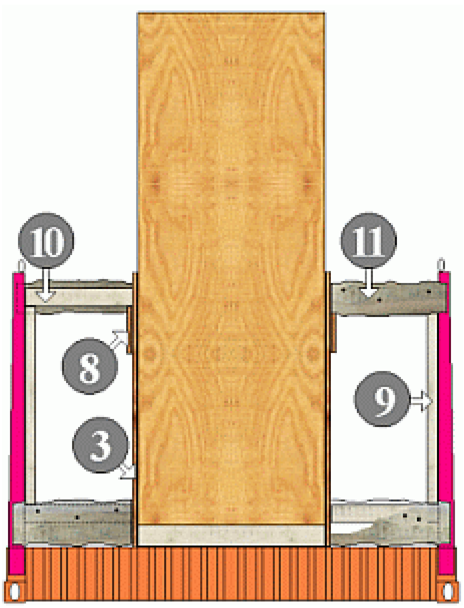


End bracing built up from below (6)



End bracing with suspended bracing members (7)

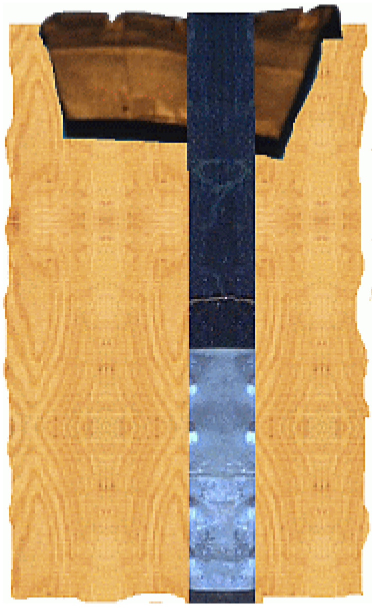




Securing against tipping by bracing against the stanchions

Lateral securing against tipping is provided approximately half-way up the package by bracing similar to that in the floor area. Eight bracing members are constructed from two boards (11) and one squared lumber member (10). These are held in place by squared lumber (9) attached vertically to the inner edge of the stanchions and boards (8) nailed horizontally to the uprights (3).

Two tie-down lashings are applied per case for the purpose of stabilization and to prevent "popping out" of the bracing under dynamic loads. At the case edges, the steel strapping lashings are tensioned over automobile tire segments, in order artificially to improve the elasticity of the steel strapping and to be able to maintain the pretension.

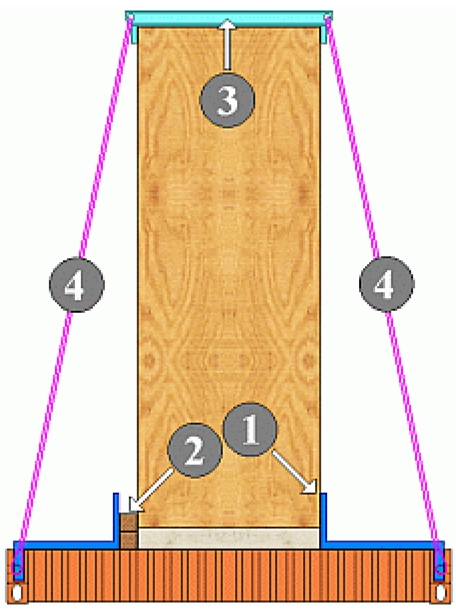


Automobile tire rubber improves elasticity and maintains pretension in steel strapping lashings.

Efficient securing options are achieved if special devices are available for cargo securing.

Transverse securing in the floor area by specially shaped stanchions

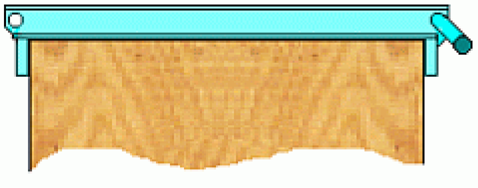
Securing against tipping using a steel crosspiece and direct lashings



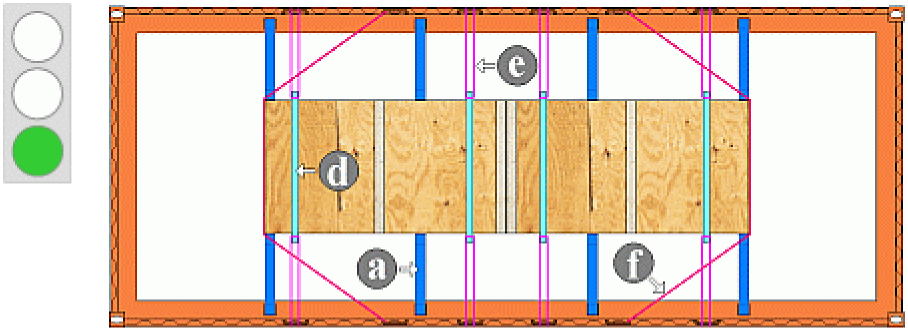
In the floor area, specially shaped stanchions can be used to secure the cases transversely either directly (1) or indirectly by using squared lumber, planks or boards (2). Securing against tipping may be achieved using direct lashings (4) passing via steel crosspieces (3).

Steel crosspieces should have appropriate lugs or angles which are capable of gripping the tops of the cases. Appropriate lashing bars, lashing rings, holes or similar components must be present, in which lashing materials such as steel wire ropes, chains, webbing belts etc. can be fastened directly or indirectly using shackles, hooks or other components. It would be sensible for such aids to be supplied directly by the producer or packer - the small expenditure should be worthwhile.

Steel crosspiece incorporated onto the case top



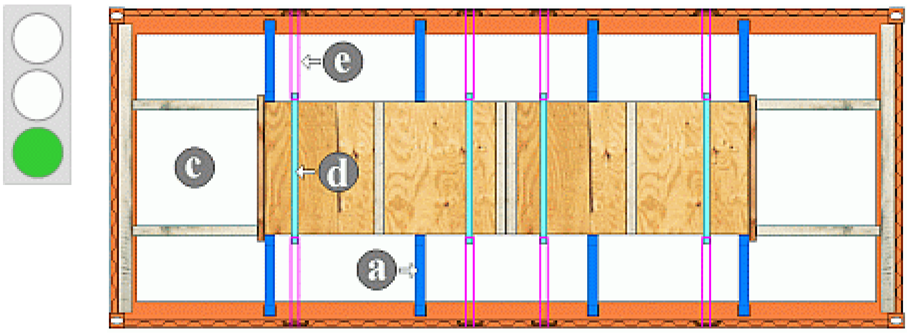
Integral lashing points should be provided as standard on large or heavy cases, since the small additional cost is more than justified by the considerably reduced shipping risk.



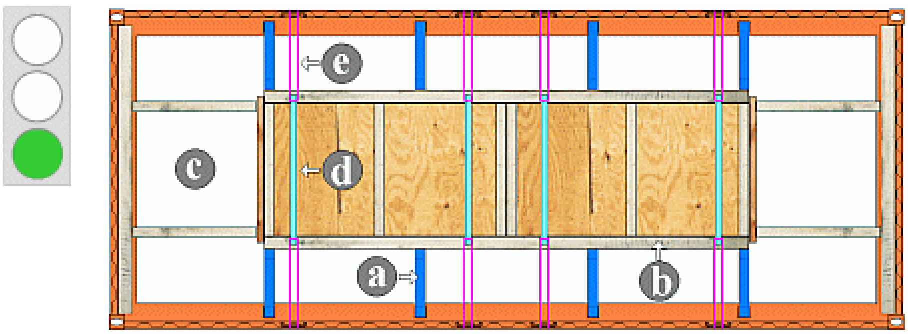
Specially shaped stanchions as transverse securing in the floor area, direct lashings for lengthwise securing and securing against tipping

The effort involved in securing using specially shaped stanchions and direct lashings is minimal. In the floor area, the cases are secured transversely by specially shaped stanchions (1 and a). The means of securing against tipping (e) are fitted to affixed or integral steel crosspieces or lashing points (d). Lengthwise securing is achieved by direct lashings (f), which are held at an appropriate height at the case corners by the vertical components of the specially shaped stanchions.

From the standpoint of labor costs, building wooden bracing (c) for lengthwise securing is more costly:



Specially shaped stanchions as transverse securing in the floor area, direct lashings for securing against tipping, bracing as lengthwise securing



Specially shaped stanchions and laterally fitted wooden members as transverse securing in the floor area, direct lashings for securing against tipping, bracing as lengthwise securing

If the dimensions of the specially shaped stanchions and cases do not allow a direct tight fit, the gaps must be filled with squared lumber (b), planks or boards. Small stowage gaps can be filled with driving wedges.

5.2.8.6 Overheight cases on flatracks, example 4

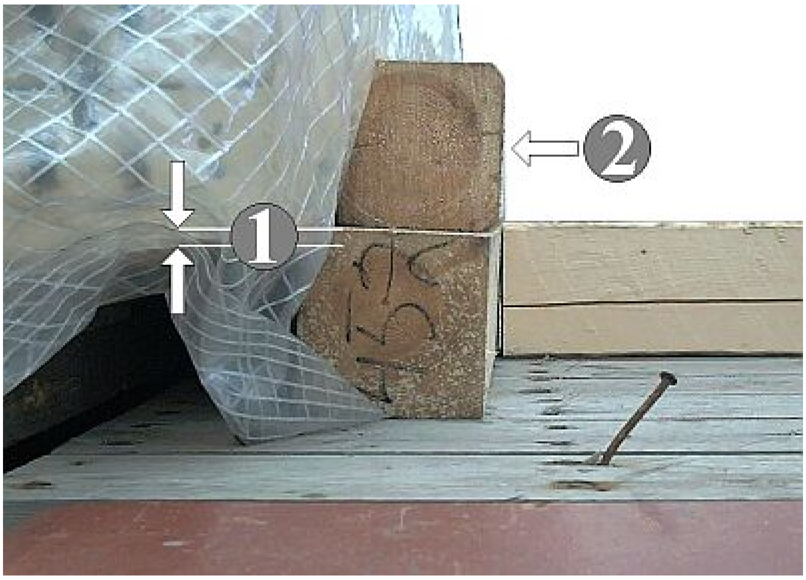
Wooden cases on a 20' flatrack, these being one overheight case and two cases of different lengths positioned next to one another

Inadequately secured cases ... from one side ...

... and from the other

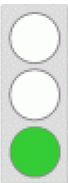
The fundamental deficiencies are:

- The inexpertly constructed wooden bracing
- The use of tie-down lashings
- The knotted webbing belts



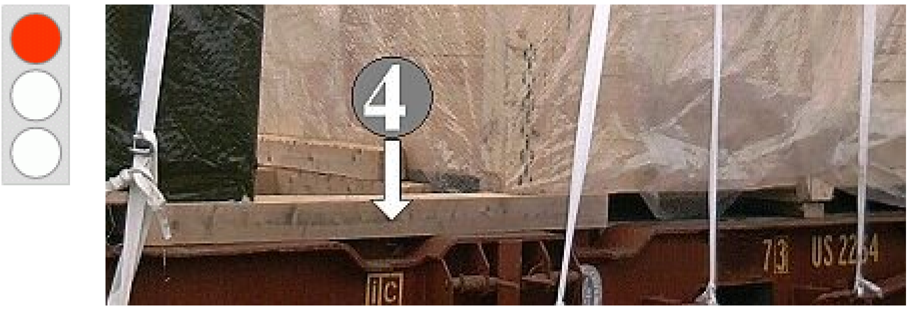
Largely ineffective bracing

The effective height of the squared lumber (1) is much too little to be able to provide appropriate bracing. Squared lumber (2) achieves nothing. The protruding nail is an accident waiting to happen.



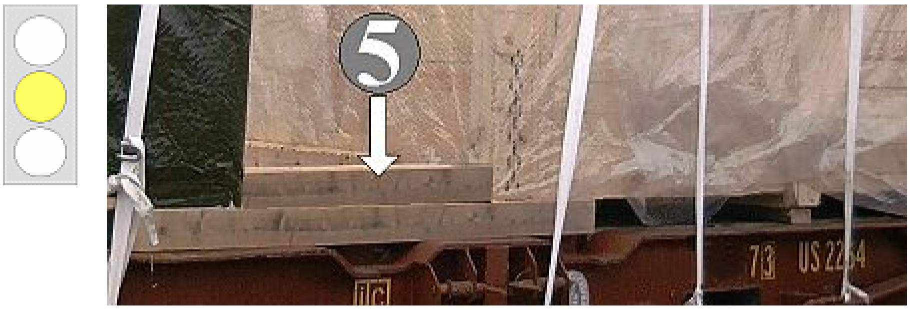
Effective bracing

By fitting in a further squared lumber member (3), effective lengthwise bracing can be achieved.



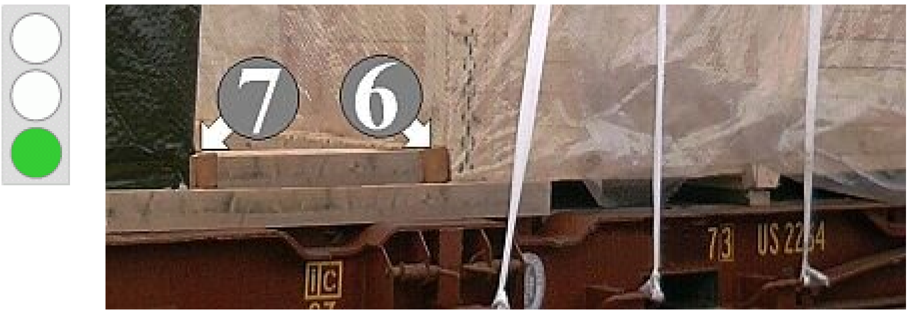
Pointless wooden member

The squared lumber (4) is performing no sensible function. It is too long for building up bracing from underneath and could have been omitted.



Effective small area bracing

Bracing can be achieved by fitting in a wooden member (5), but the supporting surface is very small.



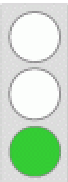
Effective bracing with appropriate pressure distribution

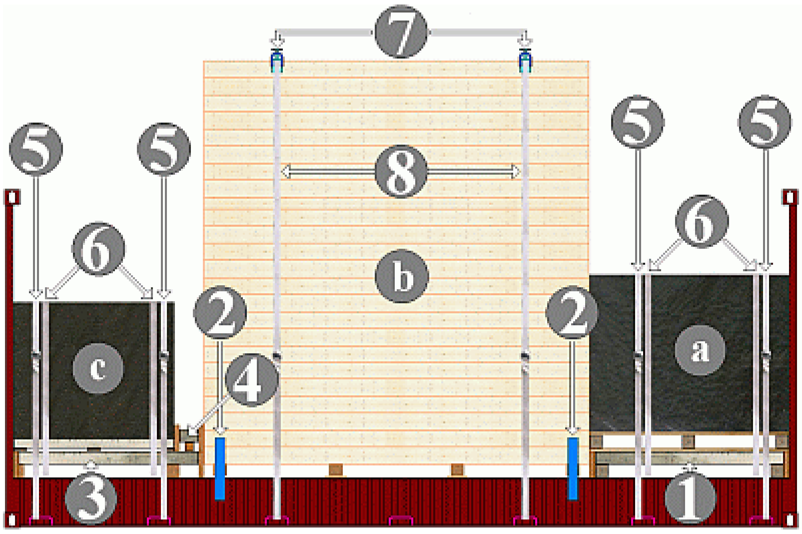
The forces arising can be distributed over a larger area by fitting crosspieces (6) (7).

Inadmissible use of textile webbing or belts

Woven webbing or belts must not be knotted. They must lie flat and must not be twisted.

Correct packing and securing of the flatrack might look like this:





All the cases secured with a tight fit on a flatrack

Wooden bracing (1) is prepared for the large case (b) and serves at the same time as a base for the case (a) to be loaded first. The height of the bracing must be such that the case (b) is braced at the bottom.

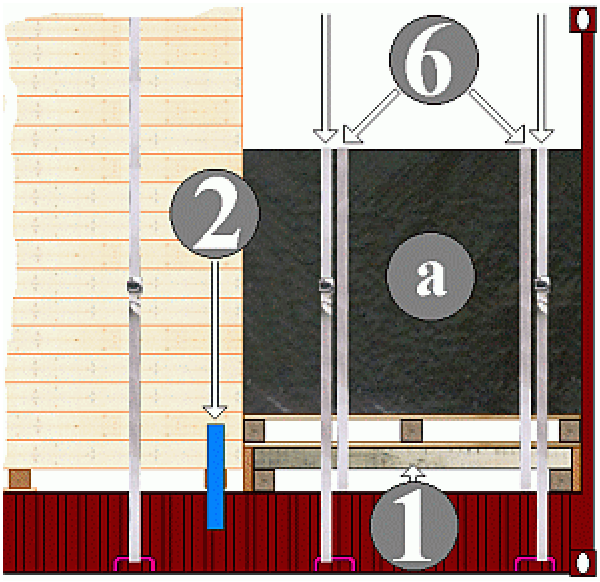
Two "case restraint shoes" (2) are so positioned on the flatrack that case (b) may be placed thereon with two of its transverse skids. So that the case does not sag at the bottom, the other two transverse skids are firred with boards which are as thick as the crossbars of the case restraint shoes.

Other securing methods for holding the case secure transversely at the bottom are feasible instead of the case restraint shoes, for example loop lashings. If a flatrack with stanchions was available, stanchions could also be inserted and lateral gaps between them and the case filled with lumber.

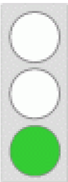
At the left-hand end of the flatrack , the case (b) is blocked with wooden bracing (3), which serves at the same time as a support for case (c), which is packed crosswise. The gap between cases (b) and (c) is braced (4).

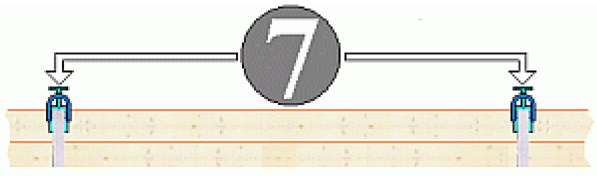
The cases (a) and (c) are each laterally secured with 2 loop lashings (5) (6). Two steel crosspieces (7) are positioned on the top of the tall case (b), to provide lashing bars for securing the case against tipping by using two direct lashings (8) on each side.

The following Figures show details of the above arrangement:

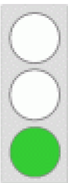


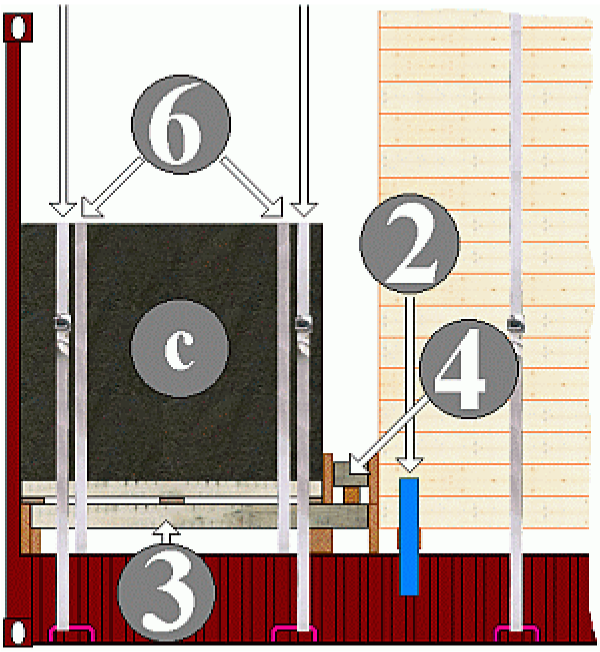
Detail of the case (a) and the right-hand side of case (b)





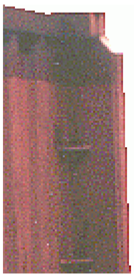
Detail of the steel crosspiece consisting of a small H-beam to which lashing stirrups with bars are welded at the sides, webbing belts being passed through the stirrups.





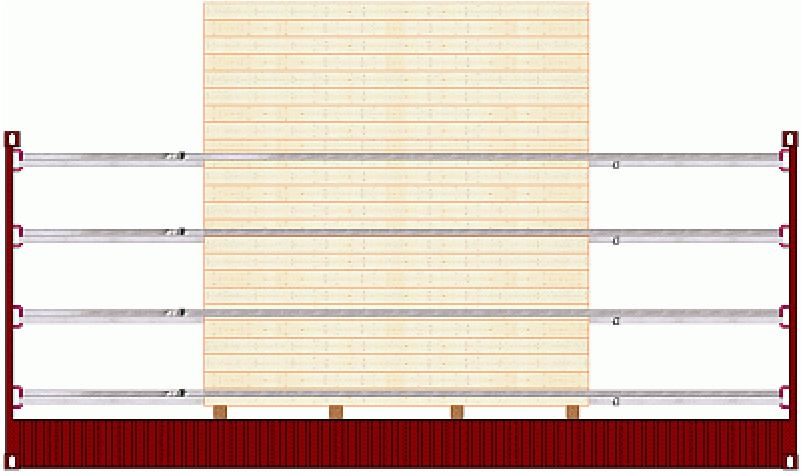
Detail of the case (c) and the left-hand side of case (b)

To provide more flexible cargo securing, it would be desirable if more container manufacturers would decide to affix lashing points fully capable of bearing loads over a quadrant to the insides of the end walls in the vicinity of or on the corner posts.

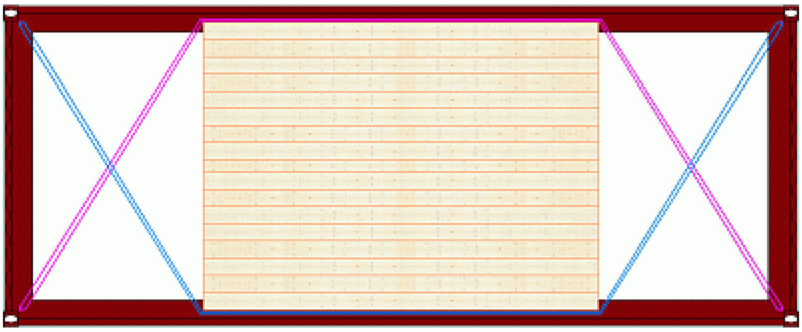


Lashing eyes on the corner posts of a flatrack end wall

The degree to which this extends securing options is illustrated by taking the tall case as an example.

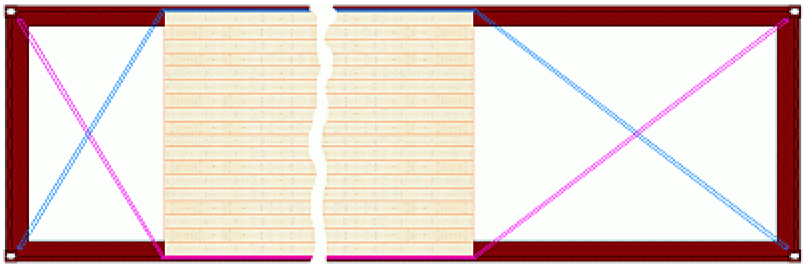


Securing using direct lashings - side view



Securing using direct lashings around the case - plan view

A note of caution should be sounded here - this form of direct lashing can only produce transverse forces. It would be different if the securing materials were attached to the case corners. However, with the angles shown, transverse forces arise which are of the order of approx. 85% of the maximum securing load of the selected securing materials. In the case of single-use webbing belts with a maximum securing load of, for example, 1,000 daN per single run, transverse forces of 2 x 0.85 x 2,000 daN = 3,400 daN could be produced per "bight" if the strapping is laid double as it is here. If it is assumed that each of the four lashing points on the corner posts has a maximum securing load of 2,000 daN, transverse securing forces of 2 x 4 x 2,000 daN, i.e. 16,000 daN could be produced on each side.



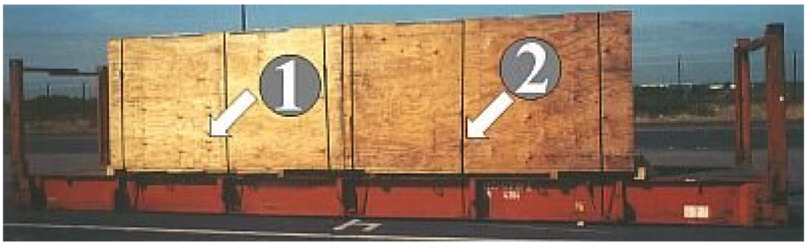
Securing using direct lashings
- plan view of two stowage variants

The decisive factors as far as the achievable cargo securing forces are concerned are the width of the shipping packages and their distance from the end walls or their position relative to the lashing points, with the resultant angles. In the left-hand variant, transverse securing forces of approx. 80% of the maximum securing loads are achieved . To the right, the transverse securing forces amount to only 60% of the maximum securing loads due to the large distance from the end wall.

5.2.8.7 Overheight and overwidth cases on flatracks, example 1

Two plywood cases on a 40' flatrack

Without performing any calculations, it is obvious that the securing means provided are inadequate.



Inadequately secured cases on a 40' flatrack
- side view

The two plywood cases each weigh 4,000 kg and are each 4.10 m long, 2.50 m wide and 2.20 m tall. Their eccentric center of gravity is labeled as required and is relatively low (at (1) and (2) in the Figure).

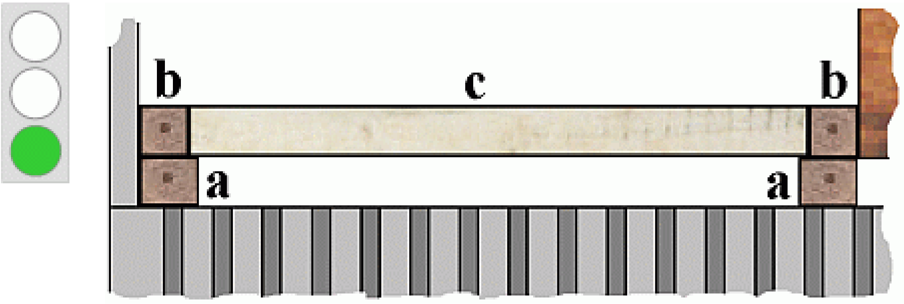
Inadequately secured cases on a 40' flatrack
- oblique view

The three steel straps used per case lose their pretension if they cut any further into the outside of the case and are then no longer able to fulfill their holding-down function. They then act as pre-loosened direct lashings predominantly only in the vertical direction.

In each case, three nails have been hammered into the four wedges, but they do not provide adequate lengthwise securing. In particular, the nails can be easily levered out of the wedges, since the wooden crosspiece laid between case and wedges has only a very low effective height (3).

Appropriate lengthwise securing can be achieved by stowing the cases so that their centers of gravity are symmetrical and blocking them against the end walls:

Variant for lengthwise securing of two cases using wooden bracing



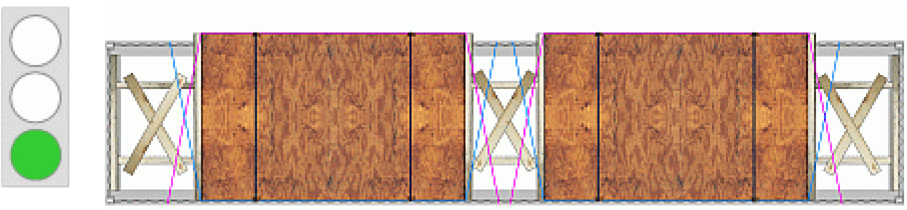
Detail of wooden bracing

In order to be able to provide bracing in the load-bearing bottom area of the cases using bracing lumber, two crosspieces (a) are placed in front of the end walls of the flatrack and the cases. The height of these wooden members must match that of the case props. Two further crosspieces (b), which must be somewhat narrower than the crosspieces (a) are placed on the crosspieces (a), to produce an appropriate abutment for the bracing consisting of the precisely fitting wooden members (c). All the wooden members must be attached to one another and the wooden members (a) to the flatrack floor. If necessary, the wooden members (c) must be X-braced together with wooden boards.

So as not have to rely on tie-down lashings for transverse securing of the cases, it is better to space them from one another and to block them:

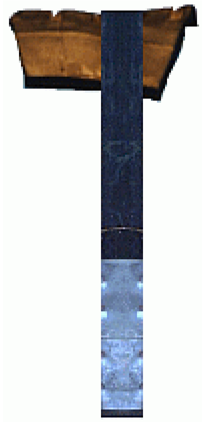
Variant for lengthwise securing of two cases using wooden bracing

The method of stowing the case is different from that originally used: the cases overhang on only one side, not both, so that only two slots are occupied instead of three.



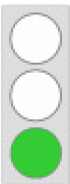
Securing of overwidth, overheight cases - side view

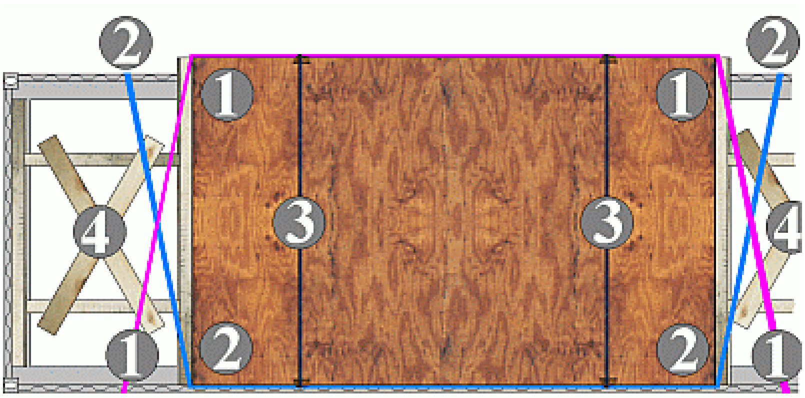
Appropriate transverse securing can be achieved using loop lashings passed around the sides. These would provide sufficient securing if the center of gravity of the cases is very low, but to avoid any risk it is advisable also to fit two steel strapping tie-down lashings per case to secure against tipping. To ensure that the steel strapping is adequately pretensioned and to prevent it from cutting into the outsides of the boxes, the steel strapping should be passed over automobile tire segments.



Steel strapping for tie-down lashings tensioned over an automobile tire segment

Detailed view:



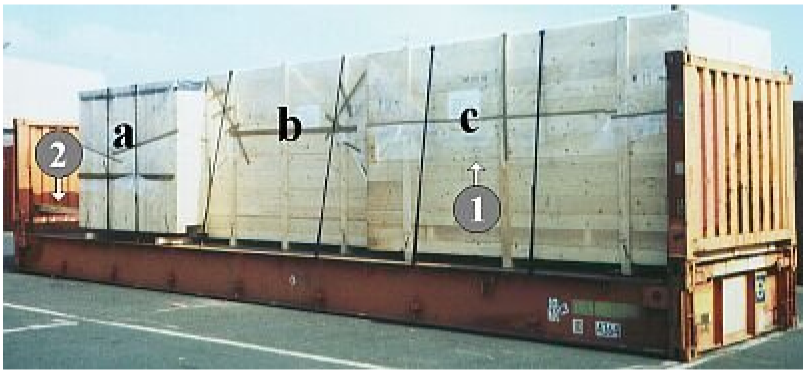


Expert securing of overwidth, overheight cases - detailed plan view

1 and 2 = horizontally arranged loop lashings for lateral securing
3 = tie-down lashings for securing against tipping
4 = X-bracing of wooden bracing

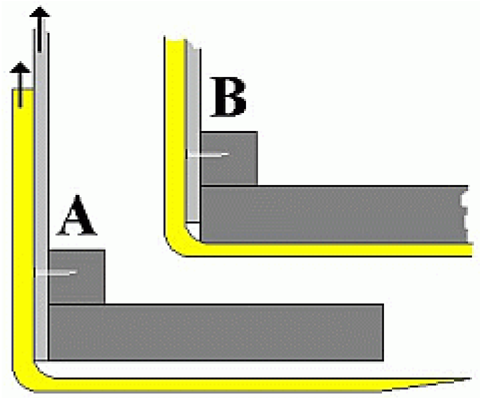
5.2.8.8 Overheight and overwidth cases on flatracks, example 2

Three wooden cases on a 40' flatrack



Three wooden cases, secured with nothing but steel strapping tie-down lashings

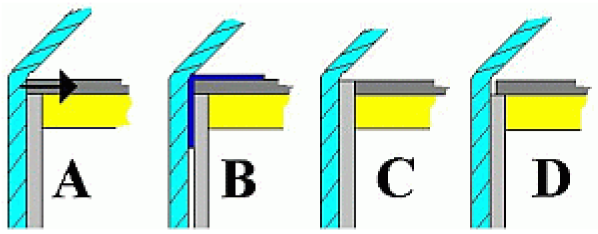
A problem with all these cases is that the side boarding ends flush with the underside of the bottom. When being picked up with forklift trucks, the boarding might be damaged by being pushed up by the channels in the fork face (see A in the Figure below):



Incorrect (A) and correct (B) side boarding arrangement

In arrangement B, the case sides end above the lower edge of the bottom by approximately their own board thickness, so meaning that the side boarding cannot be forced upwards when lifted by the forks.

The top boarding of all three cases is unfavorable, since it ends flush with the side boarding of the case (as at A). If cargo handling is not performed with frame spreader beams or spreader beams with cross beams, the vertical cable tension may pull top boards up during handling.



Incorrect (A) and correct (B, C, D) top boarding arrangement

This risk may be countered by using "heavy-lift cornerpieces" (B), lowering the top (C) or by "indenting" the top by approx. half its board thickness (D).

Another problem is that the side boarding of cases b and c is horizontal. Even small gaps between the boards considerably reduce the overall strength of the case and horizontal side boarding should only be selected if high flexural forces have to be taken up.

All three cases carry the following standard handling symbols:

- Glass, as symbol for fragile goods
- Two upright arrows, as symbol for "keep upright
- Umbrella, as symbol for "keep dry".

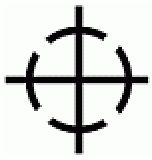
As far as the latter symbol is concerned, consideration should be given to whether the films 200 μ, i.e. 0.2 mm, thick which only partially cover the boxes provide sufficient protection against the weather. This seems less than likely, given that the overheight of the cases is sure to mean that the flatrack is stowed on deck.

The slinging symbols used on all three cases are non-standard, arrows and the word UP being used instead of the standard chain symbol:

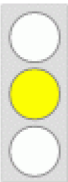
Standard "slinging" marking

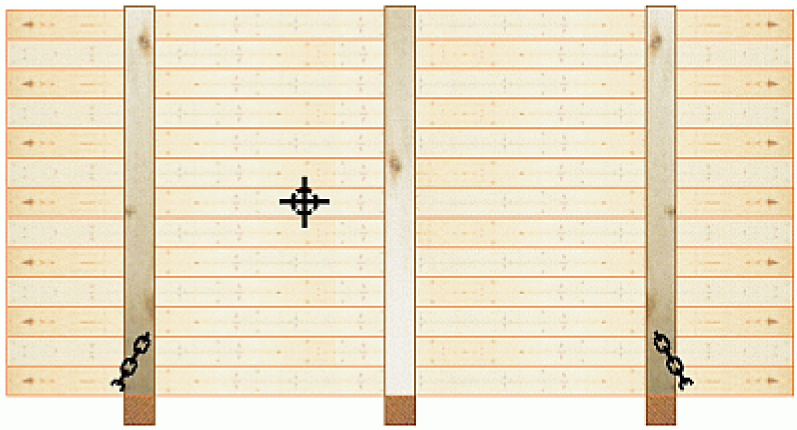
Non-standard "slinging" marking

The center of gravity of case c is off-center, a fact which is correctly marked at (1) with the appropriate DIN or ISO symbol.



Standard symbol for center of gravity

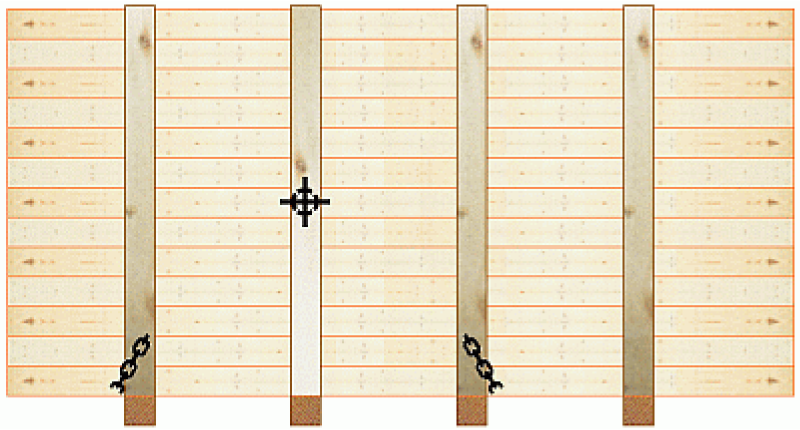




Marking of case c with regard to center of gravity and slinging (The arrows and UP have been replaced by chain symbols.)

- slinging means of different lengths have to be used.

The selected case construction and slinging point marking are completely correct, but not optimal. When the case is picked up with lifting gear, the slinging personnel must shorten the left-hand ropes so that the case hangs straight.



Optimized construction and marking

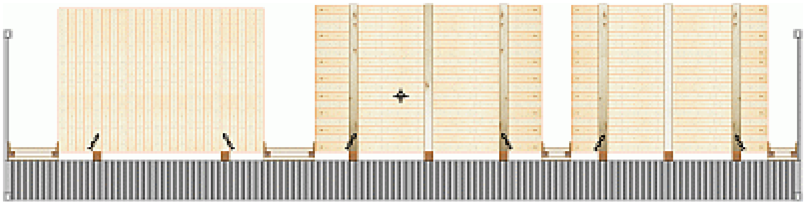
- slinging means of the same length can be used.

In this example, the case is constructed in such a way that the slinglift points are equidistant from the center of gravity, so meaning that ropes of the same length can be used.

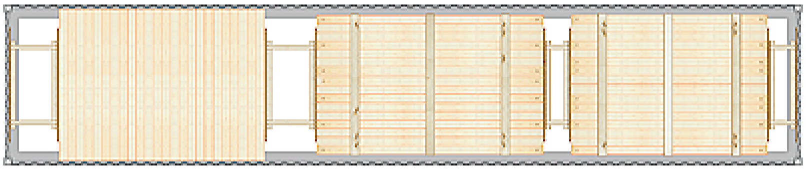
As can be seen from the first picture on this page, originally, the three cases were close-packed as a block. This kind of loading makes it difficult to use different cargo securing methods. Steel strapping tie-down lashings were therefore used, together with wooden bracing (2) in the lengthwise direction.

If loading is modified, other cargo securing methods can be used.

In this example, the cases are spaced out and again secured in the lengthwise direction by wooden bracing:

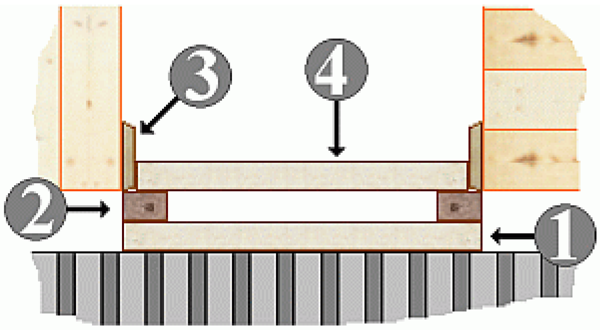


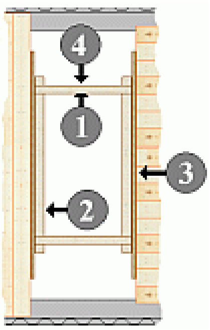
Spaced cases, cases secured lengthwise by bracing the gaps - side view



Spaced cases, cases secured lengthwise by bracing the gaps - plan view

The following Figures give a better view of the details:

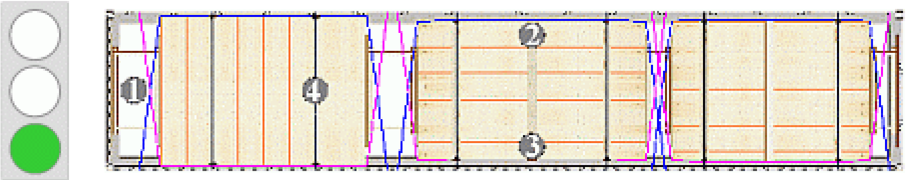




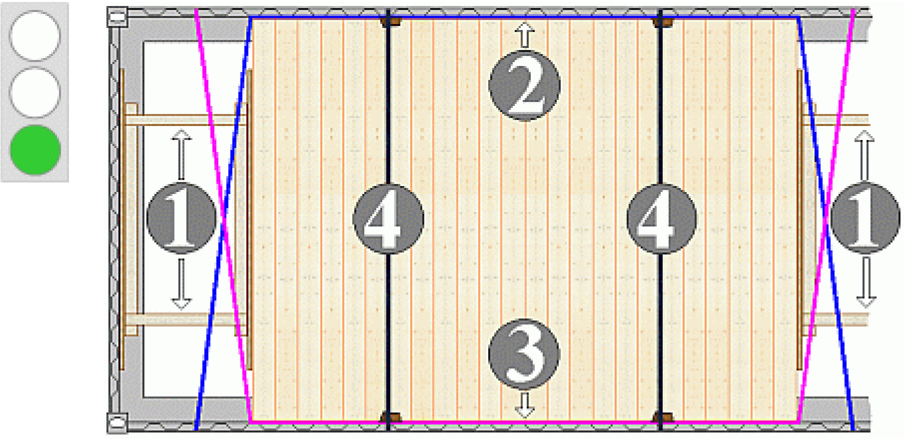
Details of bracing - side and plan view

The squared lumber (1) is laid lengthwise, at a distance from the corners which corresponds to approx. a quarter of the case width. The wooden members (2) are laid crosswise thereon. The pairs of wooden members (1) and (2) match the height between the bottom edge of the case bottom and the flatrack floor. Boards or squared lumber are positioned on the wooden members (2) to the left and right of the gap against the cases or against a case and a flatrack end wall (3) to distribute pressure. The squared lumber (4) is inserted between these wooden members for lengthwise bracing.

The cases are secured laterally by loop lashings, while securing against tipping is provided by tie-down lashings. For overall securing of the three cases, a total of four bracing members, six loop lashings and six tie-down lashings are required. The following two Figures show an overview of the securing arrangements and a detail thereof:

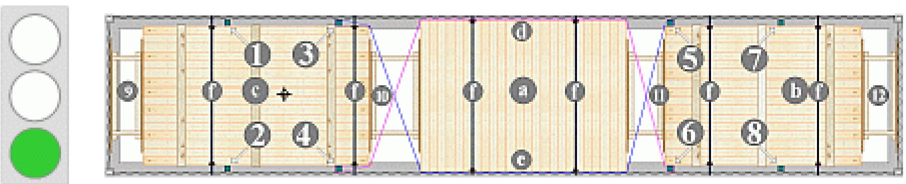


Overall securing of the cases:
Lengthwise securing using bracing (1). Transverse securing in each case using two loop lashings (2) and (3) and securing against tipping provided by in each case two tie-down lashings (4)



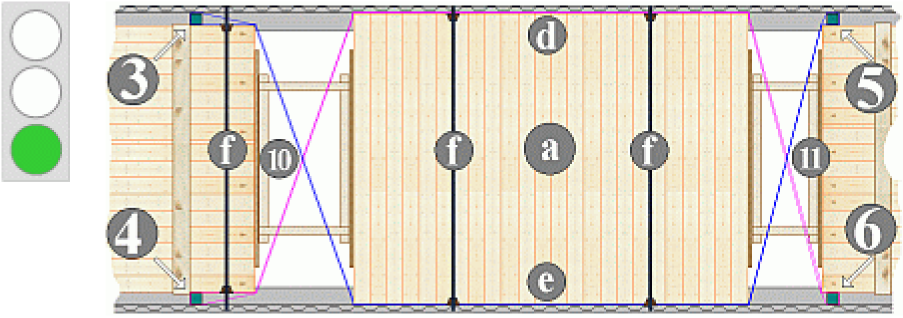
Case securing detail:
Lengthwise by bracing (1) against the flatrack end wall and the adjacent case, crosswise by in each case two loop lashings (2) and (3) and against tipping by in each case two tie-down lashings (4)

The three cases could be secured somewhat more cheaply if a flatrack with stanchions were used. The cases would be arranged differently on the flatrack, with the widest case (a) arranged in the middle and cases (b) and (c) positioned in the vicinity of the end walls, in such a way that they are secured crosswise in each case by two pairs of stanchions, case (c) being secured by stanchion pairs (1)/(2) and (3)/(4) and case (b) by stanchion pairs (5)/(6) and (7)/(8). The gaps are filled with bracing (9), (10), (11) and (12). No stanchions are used for case (a) because of its width; instead, it is secured crosswise by the two loop lashings (d) and (e). Each of the three cases is secured against tipping by two tie-down lashings (f).



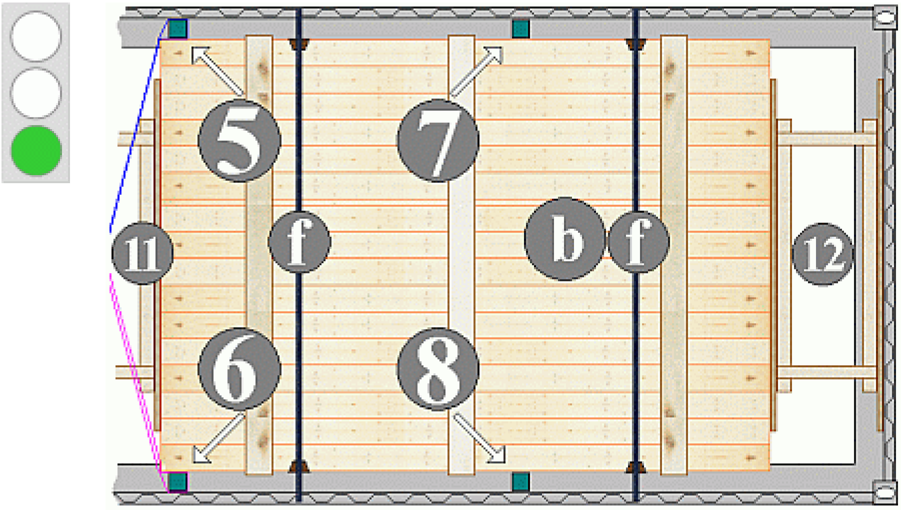
Securing of three cases on a flatrack with stanchions

To make the cargo securing clearer, the securing arrangements used here for each case are shown in detail.

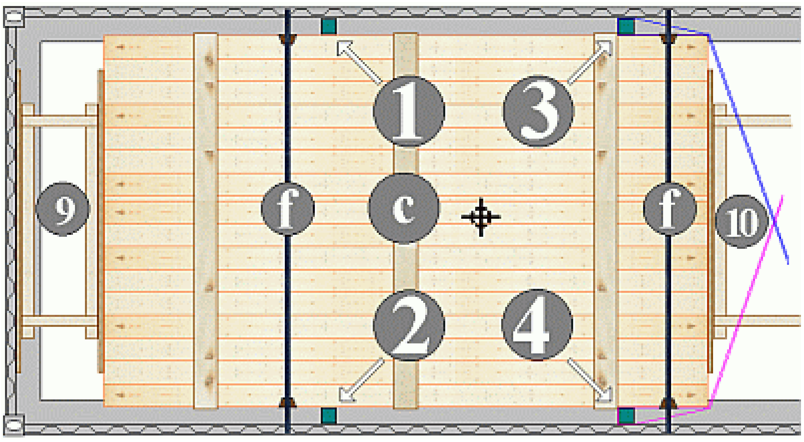


Securing of the centrally positioned case (a)

The crimson-colored loop lashing (d) extends at the level of the center of gravity of the case from stanchion(4) around the outside of the case to stanchion (6). The bluish-purple loop lashing (e) is likewise passed at the level of the center of gravity of the case from stanchion (3) around the outside of the case to stanchion (5).

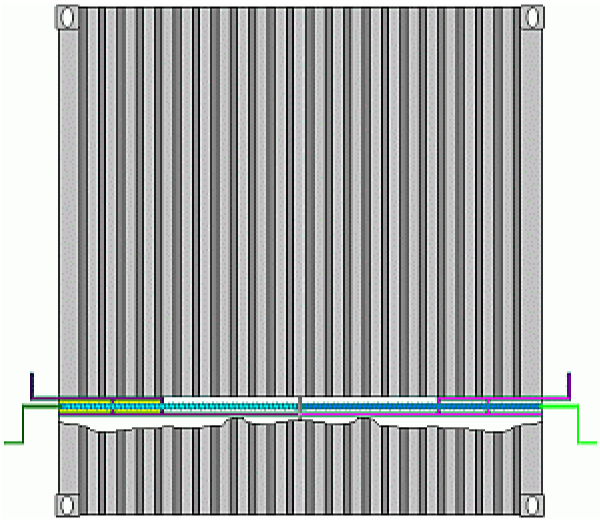


Securing of case (b) positioned in vicinity of end wall

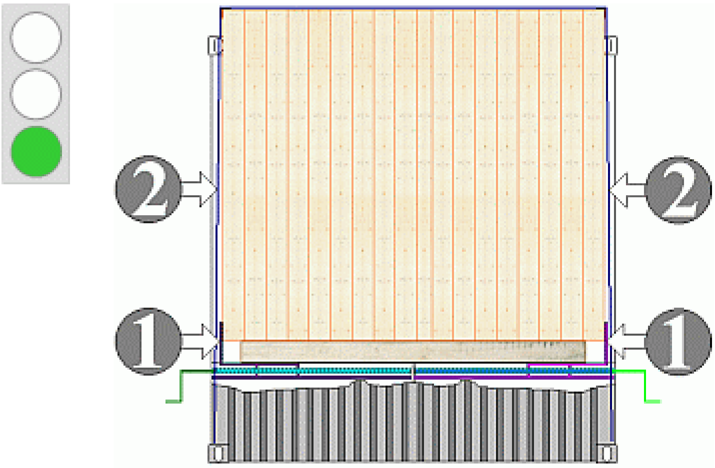


Securing of case (c) positioned in vicinity of end wall

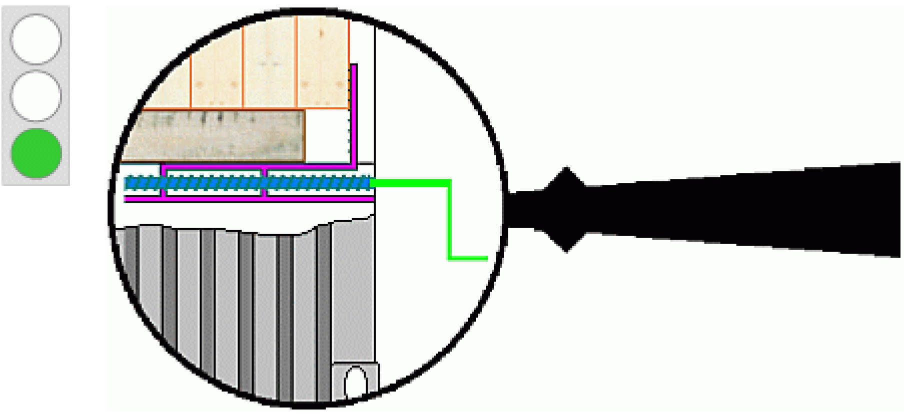
The wooden members used for bracing must be attached in such a way as to make slippage impossible. If necessary, they should be X-braced. The tie-down lashings should be positioned as far as possible equidistantly from the center of gravity of the case. When using steel strapping, the tie-down lashings should be passed over edge protectors with good recovery. Very favorable securing options would be achieved if special flatracks with clamping jaws were available for transporting large cases and similar shipping packages.



Flatrack with clamping jaws



Securing a case with spindle-guided clamping jaws (1) and tie-down lashings (2)



Detail of securing using clamping jaws

The clamping jaws must be ridged or spiked, to achieve a tight fit in the lengthwise direction by penetrating into the outside of the case. The availability of such flatracks would simplify cargo securing enormously. If the cases were expertly constructed, it would at any rate be possible to dispense with any further lengthwise and transverse securing. If conditions were particularly favorable, it would even be possible to do without tie-down lashings.

5.2.8.9 Overheight and overwidth cases on flatracks, example 3

Inadequate load distribution and securing of three wooden cases on a 40' flatrack

Incorrect load distribution and inadequate securing

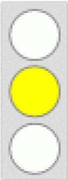
Steel strapping tie-down lashings have been fitted. Since simple plastic cornerpieces have been used, the steel strapping will press into the wooden boards of the case top under load and its pretension will gradually diminish, resulting in the loss of its securing action. With a steel strapping lashing length of 7 m, pretension would drop to zero if the strapping were to press into the top boards by only approx. 10 mm.

Another problem is that the front case is overwidth and is nonetheless secured with tie-down lashings.

Securing by the wedges nailed in front of the cases has virtually no effect, since the effective height of wedges (1) and (4) is minimal and that of wedges (2) and (3) immaterial.

Use of very close fitting wooden bracing ensures adequate lengthwise securing:

Using wooden bracing instead of wedges

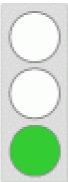


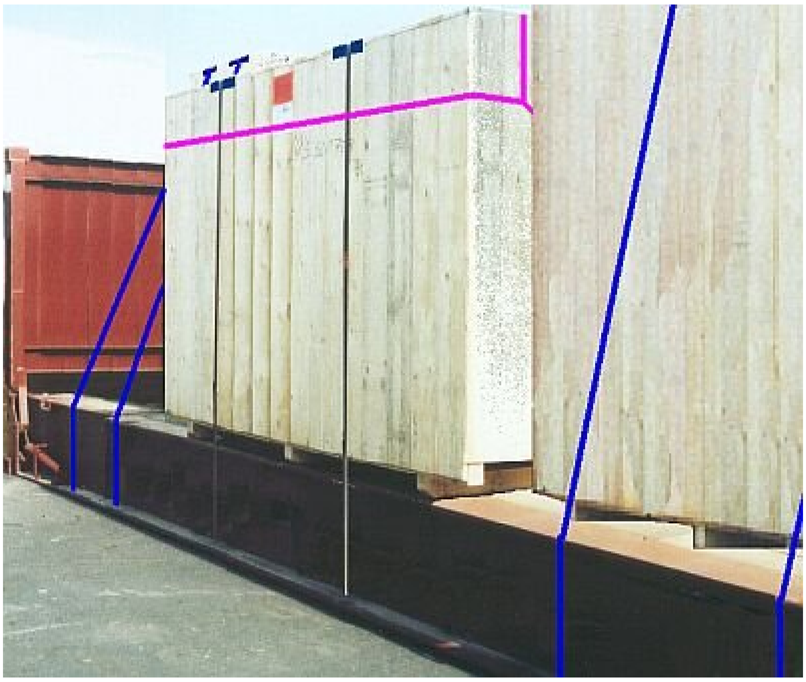
Options for maintaining pretension

Heavy-lift cornerpieces, as shown at (1), are rigid and allow prestressing forces to be maintained under favorable conditions. It is better to use edge protectors of a resilient material with good recovery properties - such materials, as with a piece of tire at (2), allow maintenance of pretension under usual carriage conditions.

The load distribution on the flatrack contravenes the regulations outlined in particular in the CTU packing guidelines, which state:

> *3.2.5 The weight of the cargo should be evenly distributed over the floor of a container. Where cargo items of a varying weight are to be packed into a container or where a container will not be full (either because of insufficient cargo or because the maximum weight allowed will be reached before the container is full), the stow should be so arranged and secured that the approximate center of gravity of the cargo is close to the mid-length of the container. If it is not, then special handling of the container may be necessary. In no case should more than 80% of the load be concentrated in less than half of the length of a container measured from one end. For vehicles, special attention should be paid to axle loads.*





Acceptable packing and securing of the flatrack

By calculating the moments, the best position may be determined for the cases. The Figure shows roughly how they might be packed and secured:

- All the cases are positioned on strips of friction-enhancing material.
- The heavy overwidth case is positioned in such a way that the center of gravity lies approximately one meter to the left of center. It is secured against lateral shifting and tipping by using spring lashings with two direct lashings.
- The lightest, tall, slim case is packed to the left thereof and blocked against the end wall.
- The medium-weight case is positioned in front of the overwidth case and braced against the other end wall.
- Each case has two tie-down lashings.

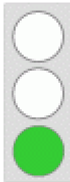
5.2.8.10 Overheight and overwidth cases on flatracks, example 4

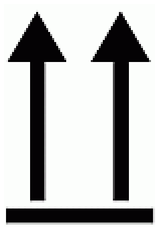
Single case on a 20' flatrack

Inadequate packing of a 20' flatrack with an overwidth case

A few hints are required with regard to packaging and securing. The standards state that marking should preferably be in black and expressly prohibit the use of scarlet.

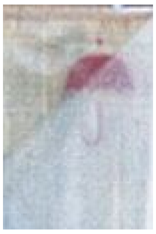
Unclear marking



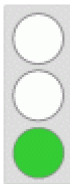


Correct marking

The single arrow symbol (a) with the word UP is not standard. As an abbreviated version of "This way up", it means that the case should be carried upright, which is normally symbolized by two upright arrows.



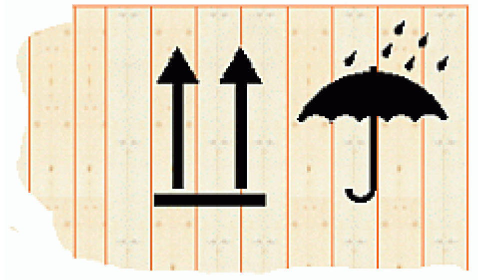
Inadmissible color: scarlet



Admissible color: black

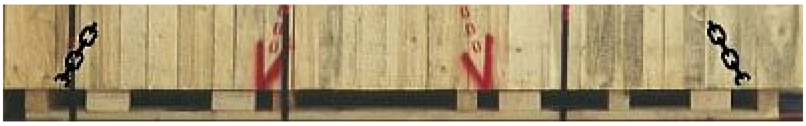
The incorrect choice of color for the symbol (b) is of course a minor defect. What is more important is that the case, which needs to be kept dry, is only partially covered with a simple PE film 200 µ thick. This film will definitely not keep the package dry during a voyage, especially not if the flatrack is stowed on deck. Depending on its stowage space, the film will be damaged by exposure to the wind and possibly also by solar radiation.

Correctly affixed information marks



The symbols relevant to handling of the case should be affixed together as far to the top right as possible on two sides, which again is not the case here.

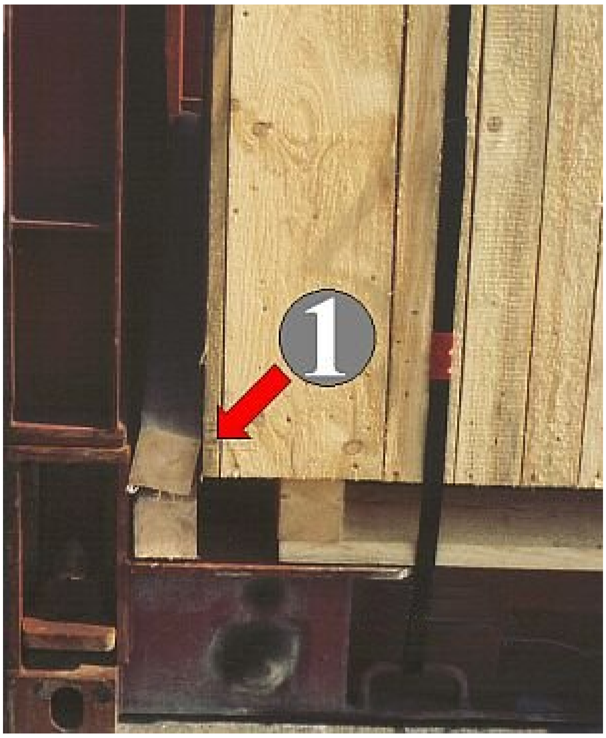
The marking relating to slinging of the case (c) is not standard either, but the least favorable feature is that the case has been so constructed that the slinglift points lie very close together and there is a risk that the case may fall out of the slinging means. There is no need to go into this unnecessary cargo handling risk.



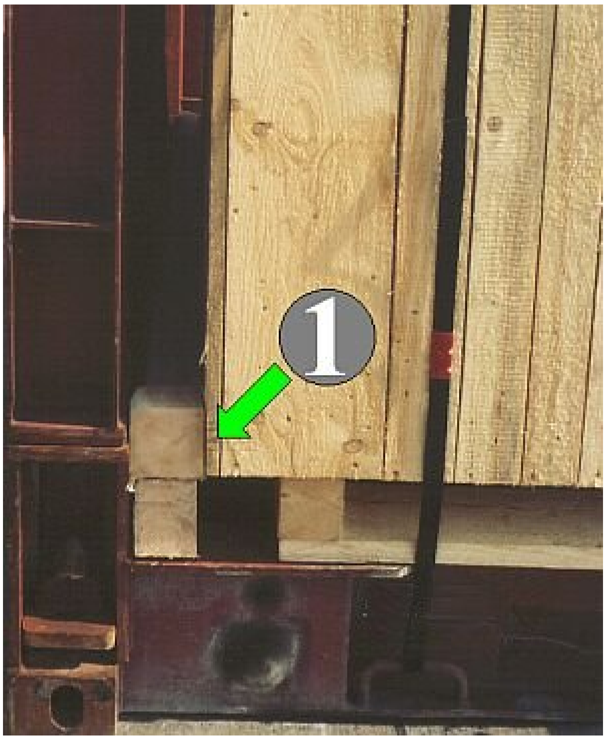
Red: unfavorable slinglift points
Black: favorable slinglift points

At (d), the mass of the case is stated as 4600 kg. Calculation of the moments shows that the center of gravity of the packed flatrack is more than 60 cm away from the middle of the flatrack, which is inadmissible.

The cargo securing is inadequate. The crosspiece (1) is too low - it does not lie with its whole height against the bottom of the case. Other shapes or the additional use of a board could put things right.

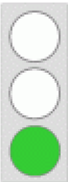


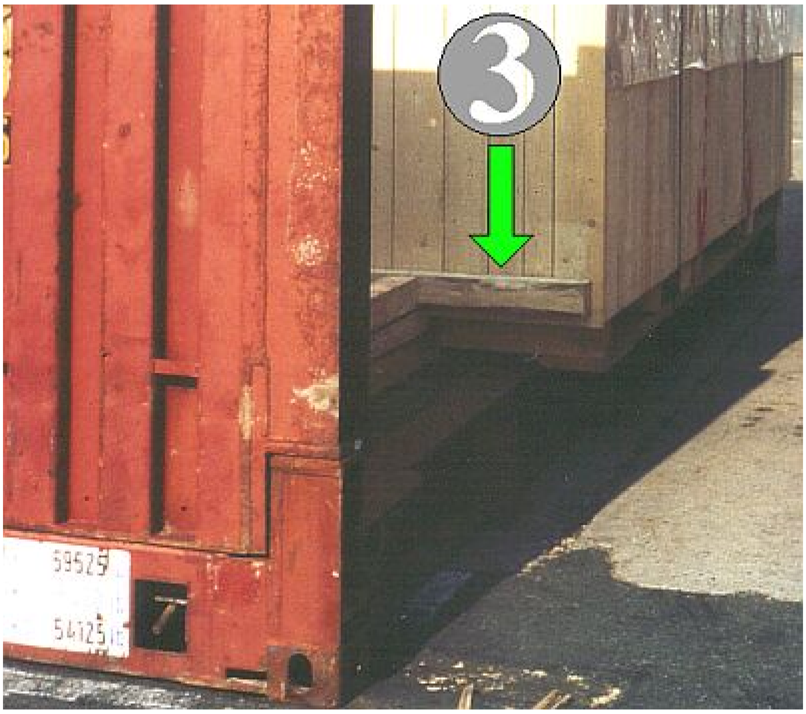
Incorrect position of the squared lumber



Correct position of the squared lumber

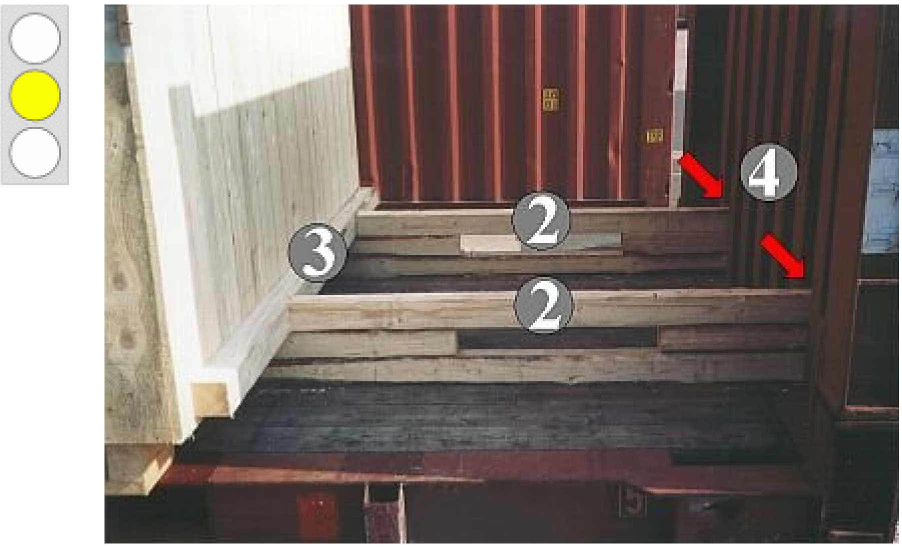
The cross piece (3) is correctly positioned, and transmits the forces into the case bottom:





Correctly positioned crosspiece for lengthwise securing (green light)
But: inadequate transverse securing (red light)

The lengthwise wooden members (2) are correctly positioned, but apply point loads to the end wall of the flatrack at (4).



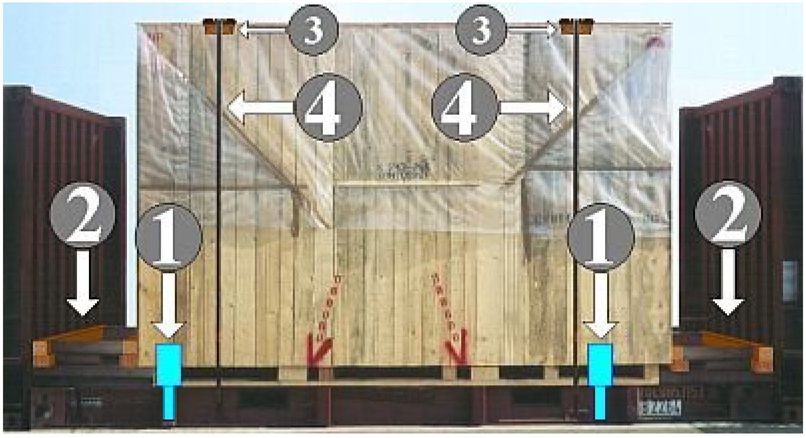
Point-loading of the flatrack end wall by the lengthwise wooden members

An additional squared lumber member fitted against the end wall can effect pressure distribution.

Correct pressure distribution by an inserted crosspiece

The tie-down lashings (5) are stretched over the case top and film without further measures. They are already cutting visibly into the lumber and damaging the film and will not in the long term retain the pretension required for securing. The problems with using tie-down lashings on overwidth packages have already been discussed.

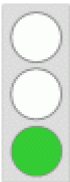
Appropriate securing might have looked like this:

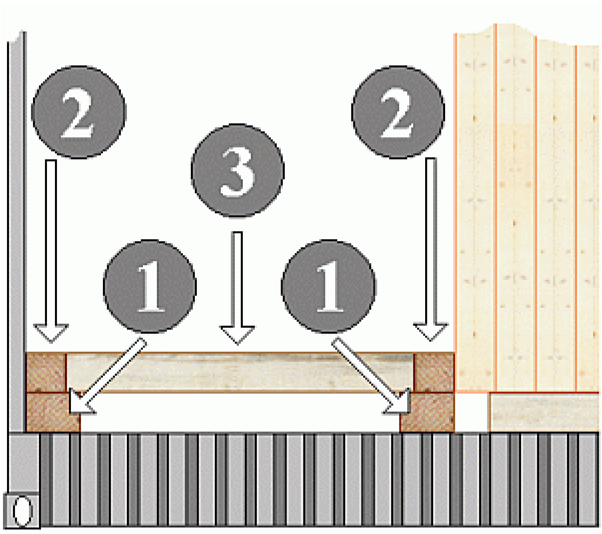


Correct securing of the overwidth and overheight case

The shipping package is loaded centrally. The overwidth case is secured laterally by special "case restraint shoes" (1), the design and mode of action of which will be described below, with possible alternatives. Lengthwise securing is achieved with wooden bracing (2), which consists in each case of two crosspieces and lengthwise members, which are "chocked up" far enough for them to transfer forces in the area of the case bottom.

The two steel strapping tie-down lashings (4) are designed to hold the case in the "case restraint shoes". In order to protect the case and ensure their efficacy, they are tensioned over cornerpieces of elastic material (3).

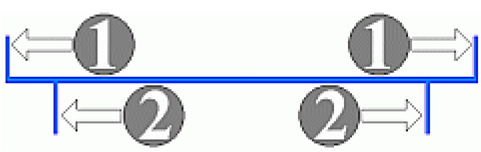




Expert bracing

To shore the case, squared lumber of rectangular cross-section is selected (1), whose narrow side matches the height of the "case restraint shoes". The wooden members are positioned crosswise in front of the case and the flatrack end wall. On these are laid square or rectangular lumber (2), whose dimensions are somewhat smaller than those of (1). It is important for the wooden members (2) to be able to rest against load-bearing parts of the case, the best place being the bottom area of the case. Squared lumber (3) is fitted between these wooden members and lies on the protruding part of the wooden members (1).

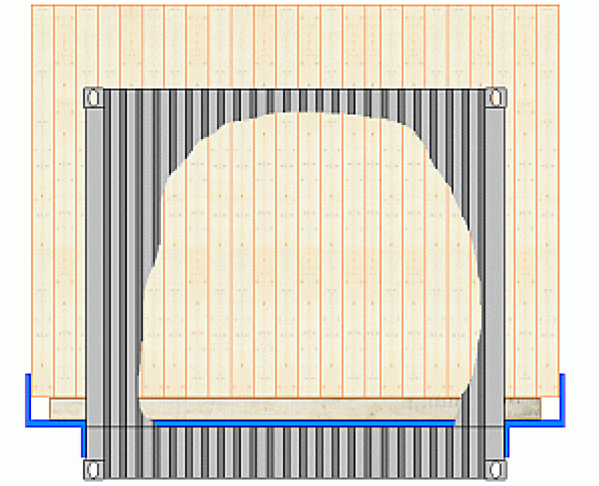
To ensure securing of their own product, the exporting company should provide "case restraint shoes", given that they know that their case is an overwidth case and will have to be transported on a flatrack.

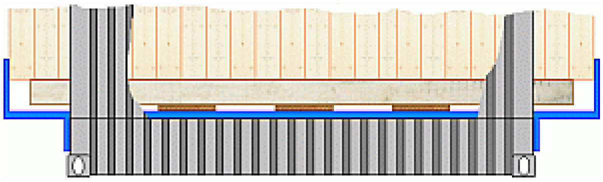


Case restraint shoes

The case restraint shoes may be easily made from flat or profiled steel. The distance between the upper lugs (1) must match the width of the case, that of the lower lugs (2) the width of the flatrack. At least two of these shoes are positioned on the flatrack at suitable points and the case is loaded onto them.

Tight-fit lateral securing of a package in case restraint shoes



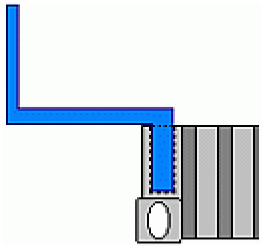


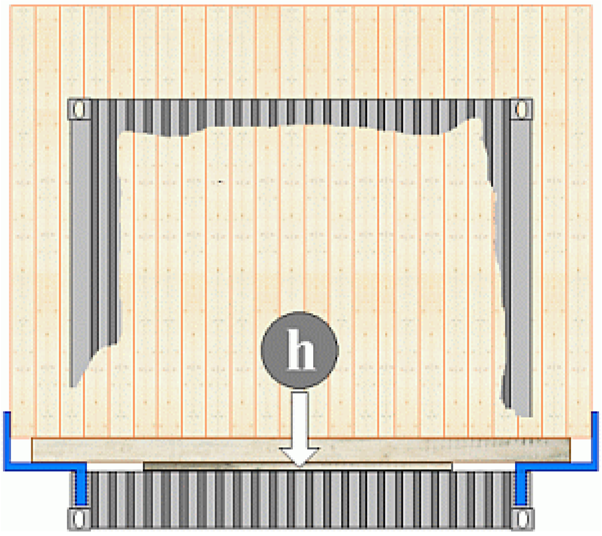
Longitudinal planks between case and case restraint shoe

It is important for the lugs of the case restraint shoes to be "meaty" enough to hold the case. Slight dimensional tolerances between the lugs of the case restraint shoes and the cases can be compensated with hardwood driving wedges.

It would be better and more favorable if flatracks with stanchion pockets were commercially available which carried a corresponding number of different-sized specially shaped stanchions. This would markedly improve and rationalize the securing of many cargoes.

Specially shaped stanchion for a 20' flat - for insertion into stanchion pockets

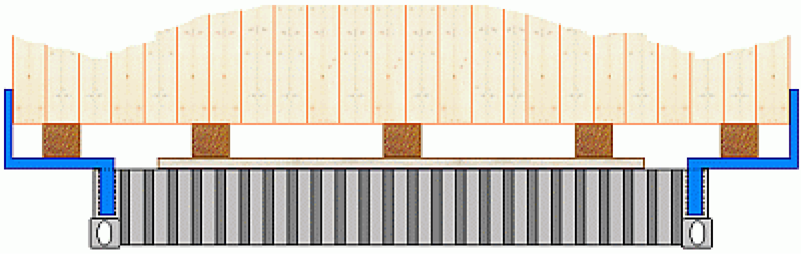




Use of two specially shaped stanchions for securing a case on a 20' flatrack - crosspieces are positioned beneath the case to prevent its bottom from sagging

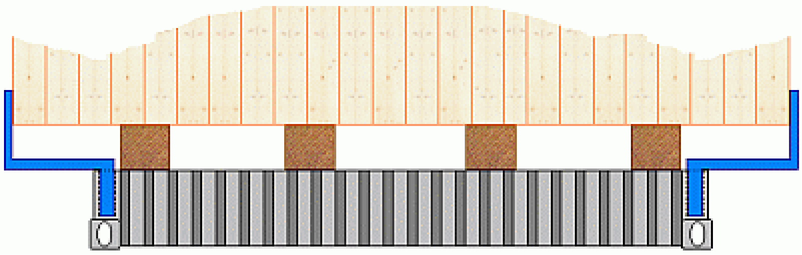
In the case of cases with transverse skids, crosspieces or lengthwise members corresponding in height to that of the horizontal specially shaped stanchion components should be laid under the case bottom to support it against sagging (h).

Measure taken against sagging of the bottom: lengthwise wooden members laid thereunder



Measure taken against sagging of the bottom in cases with longitudinal skids: crosspieces laid thereunder

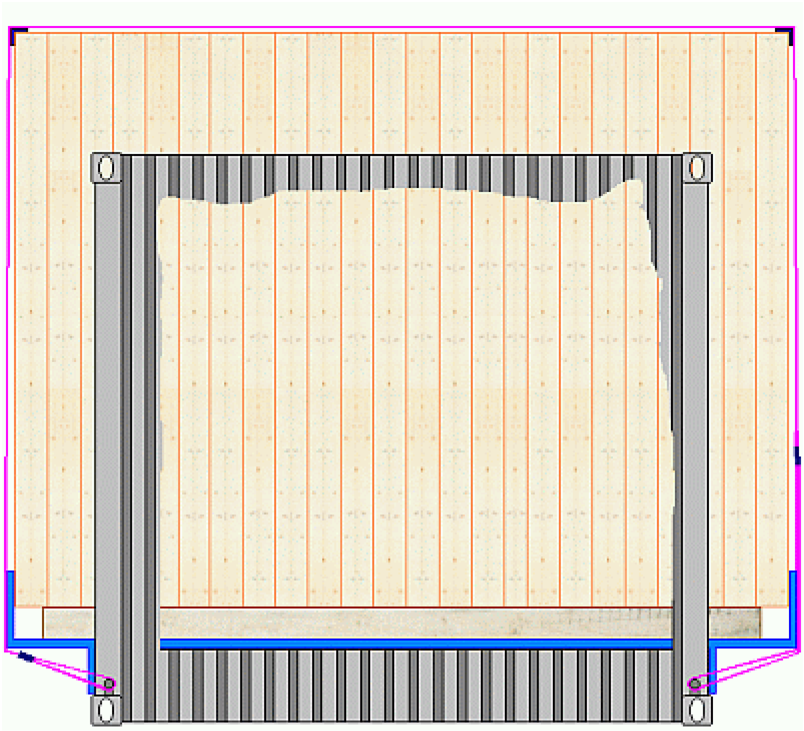
Firring should also be provided in the case of cases with longitudinal skids, if the outer longitudinal skids stand on the specially shaped stanchions.



No measures need be taken against sagging of the bottom, if the case restraint shoes apply load to the load-carrying parts of the flatrack.

Firring can be omitted if the longitudinal skids are free of the specially shaped stanchions and the load is evenly distributed over load-carrying container components.

To hold the packages in the case restraint shoes or specially shaped stanchions, at least two tie-down lashings are also fitted per shipping package.



High quality securing of a case using case restraint shoes and tie-down lashings

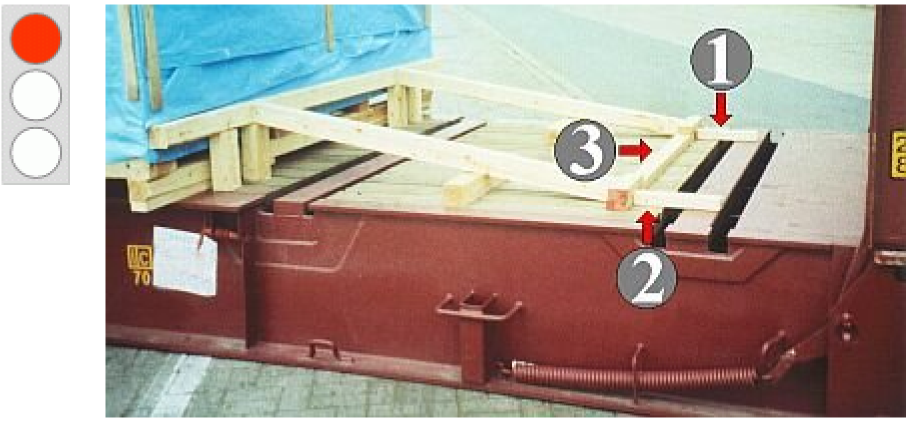
The tie-down lashings act in this and similar cases to prevent "popping out" of the case restraint shoes or specially shaped stanchions under dynamic loads. They are actually being used here as direct lashing.

5.2.8.11 Overheight and overwidth cases on flatracks, example 5

Two cases of approximately equal weight on a 40' flatrack

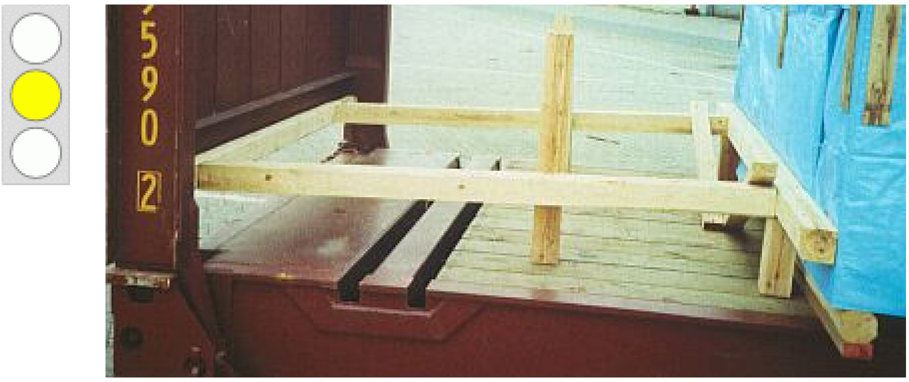
Inadequately secured cases on a 40' flatrack

It is immediately obvious that the lengthwise securing on the right-hand side of the flatrack is inadequate, since nailed-on wooden members have been used. To assess the rest of the securing arrangement, a closer look is required. Positive features are that the weather protection is better than that provided for the previous cases and that the steel wire tie-down lashings are passed over elastic edge protectors.



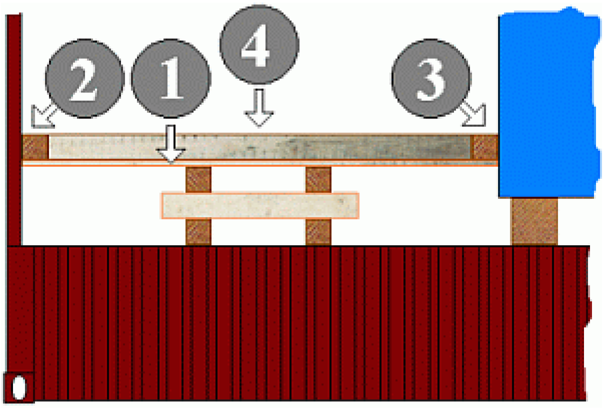
Inadequate securing with wooden fixings

When building the technically skillful construction, no consideration was given to the fact that only the shear action of the nails hammered into wooden members (1), (2) and (3) is relevant to the strength of the overall structure. Depending on the thickness of the flatrack planking and the selected wire nail diameters, together with their depth of penetration into the wooden members and the floor, cohesive resistance of approx. 100 - 400 daN per nail may be anticipated.



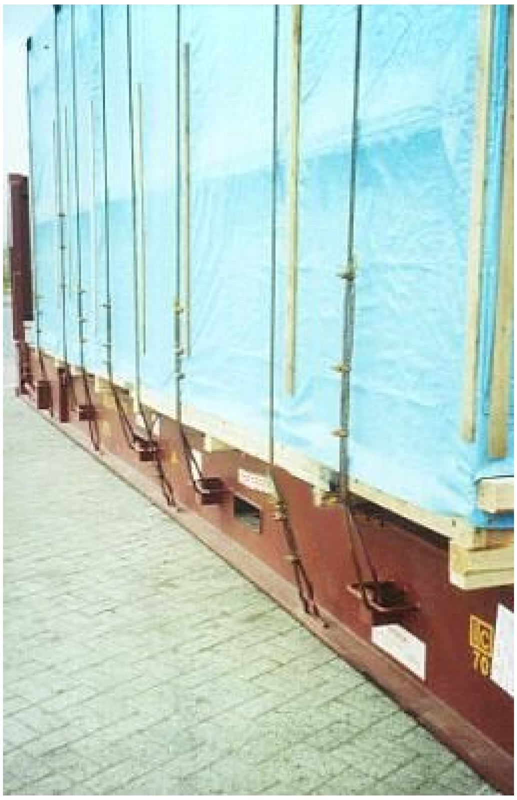
Wooden bracing on the left-hand side of the flatrack

The bracing on the left-hand side of the cases is passable. However, it must be ensured that the bracing cannot loosen, for which purpose the squared lumber must be carefully tacked down. The following approach is somewhat more elegant.



Variant of bracing on left-hand side

Depending on the desired height, a number of wooden members laid cross- and lengthwise are used as a base. Two boards (1) cut to the right dimensions are laid lengthwise thereon. The wooden members (2) and (3) serving to distribute pressure are placed crosswise on the ends thereof. Finally, the wooden members (4) need to be cut precisely to size and fitted in place.



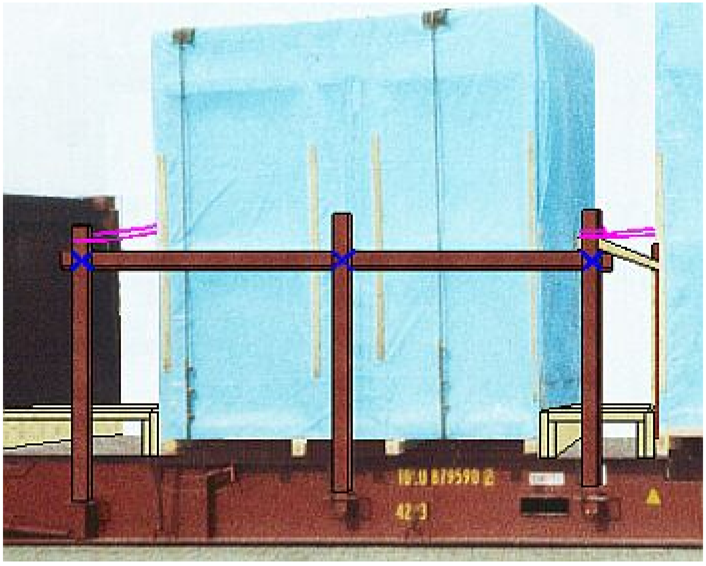
Inadequate securing against crosswise and tipping movement using tie-down lashings

The front case is secured with five tie-down lashings made from steel wire ropes 16 mm in diameter, while the rear case is secured with three. The maximum securing load of the wire ropes may be calculated by rule of thumb in decanewtons on the basis of d x d x 40, i.e. 16 x 16 x 40 = 10,240 daN. If three wire clips are used, a maximum of 7,680 daN is achieved per single run of lashing. The lashing points used have on average a maximum securing load of approx. 3,000 daN. The wires are pretensioned with turnbuckles. If the maximum allowable pretension is 50% of the admissible lashing force on each side, a total of 2 x 1,500 daN = 3,000 daN pretension could be applied per lashing. Assuming a coefficient of sliding friction of μ = 0.2, securing forces of 600 daN should be anticipated per tie-down lashing. The reduction in forces due to the lashing angle of approx. 70° was disregarded. The large case has accordingly been secured by the tie-down lashings in all horizontal directions with 5 x 600 daN = 3,000 daN, while the small one has been secured with 3 x 600 daN = 1,800 daN. By using friction-enhancing material with a possible coefficient of sliding friction of μ = 0.4 under the stowed cargo, the values could have been doubled.

The best possible securing arrangement for the two cases would be:

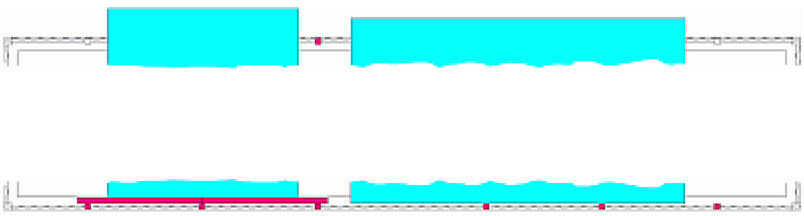
- use of case restraint shoes or specially shaped stanchions for lateral securing
- use of two tie-down lashings in each case to secure against tipping
- application of wooden bracing for lengthwise securing

The fact that the flatrack has stanchions and stanchion pockets at the sides opens up the way to another securing variant, which is possible if the unilaterally overhanging cargo does not cause the center of gravity of the flatrack to lie inadmissibly far from the longitudinal center line.



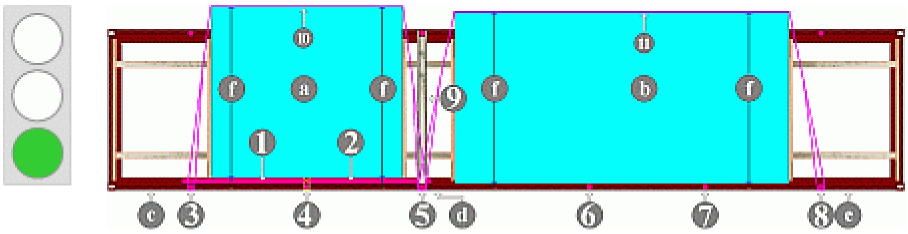
Securing variant for unilaterally overhanging cargo, using the stanchions provided (selective enlargement below)

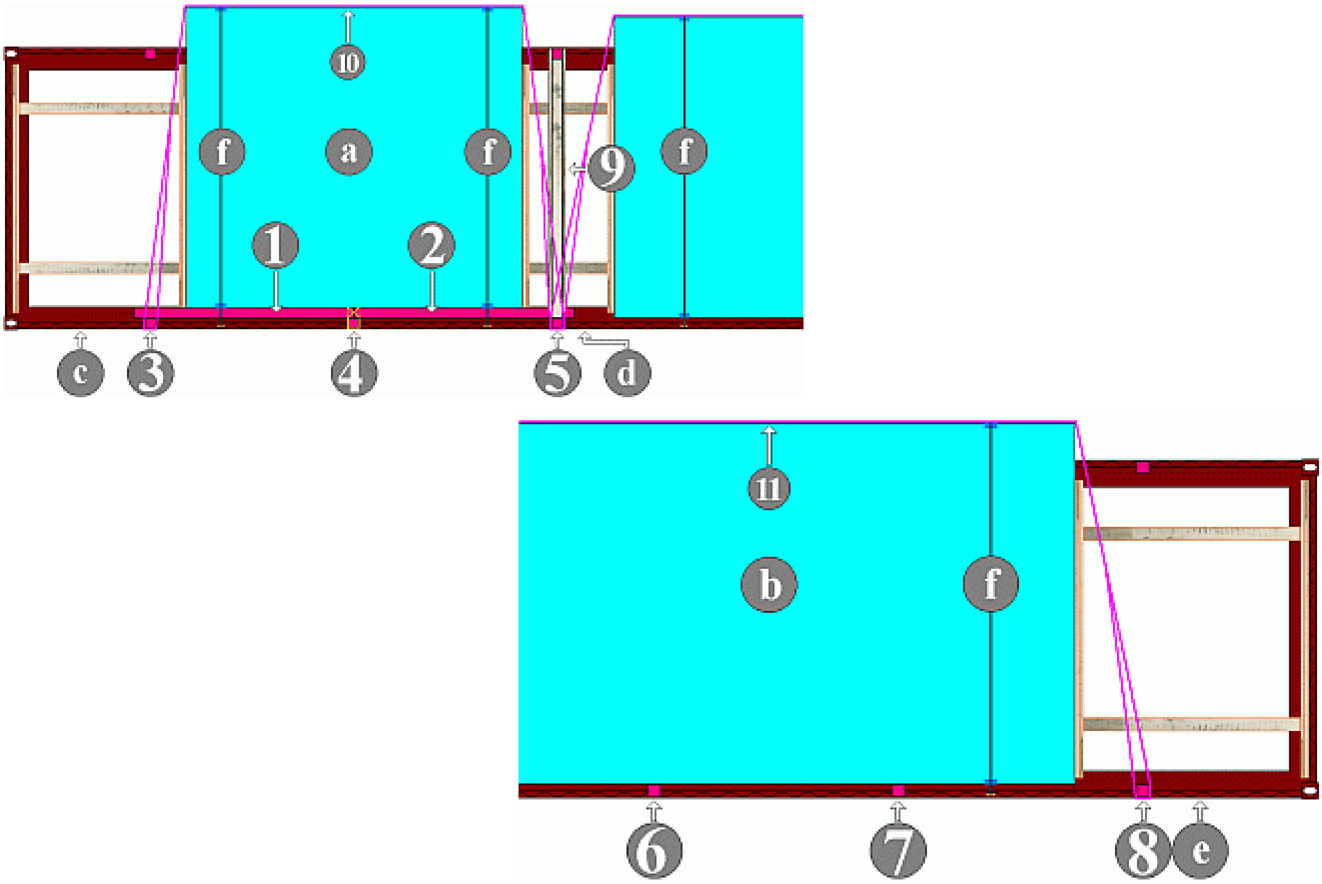
On the side of the flatrack remote from view, the third stanchion from the left is inserted. On the visible side, all the stanchions are inserted. A squared lumber member is fastened vertically to the inside of each of the three front stanchions on the left-hand side. The height of these squared lumber members should correspond to half the case height. Two of the unused stanchions from the other side are laid lengthwise on these squared lumber members and attached to the stanchions.



Inserted stanchions on the flatrack sides - plan view

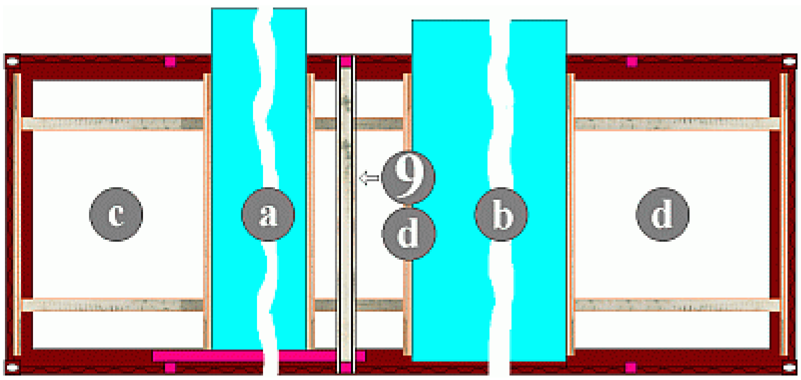
The two cases are loaded and secured as illustrated.





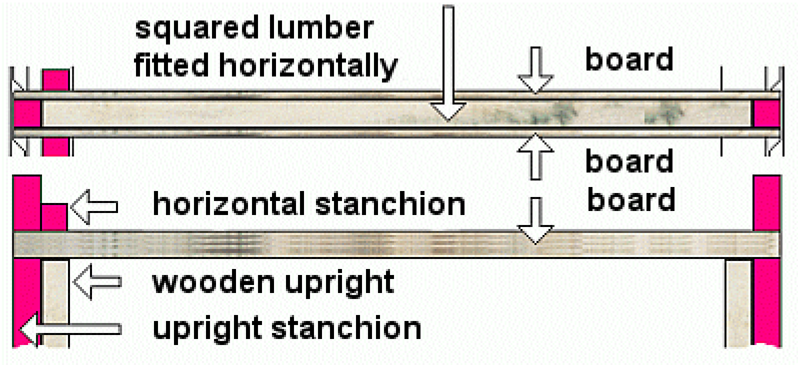
Overview of securing arrangements
(center and bottom: enlargement of the first picture in two halves)

Case (a) is supported by means of the horizontally attached stanchions (1) and (2), which are fastened to the inside edge of the stanchions (3), (4) and (5). Case (b) is supported against stanchions (6) and (7). Bracing is provided in gaps (c), (d) and (e) between the cases and the end walls of the flatrack and those between the cases in the form of squared lumber and planks. Likewise, the stanchion (5) is braced crosswise at (9) with the opposite stanchion. The bracing is shown in detail below:



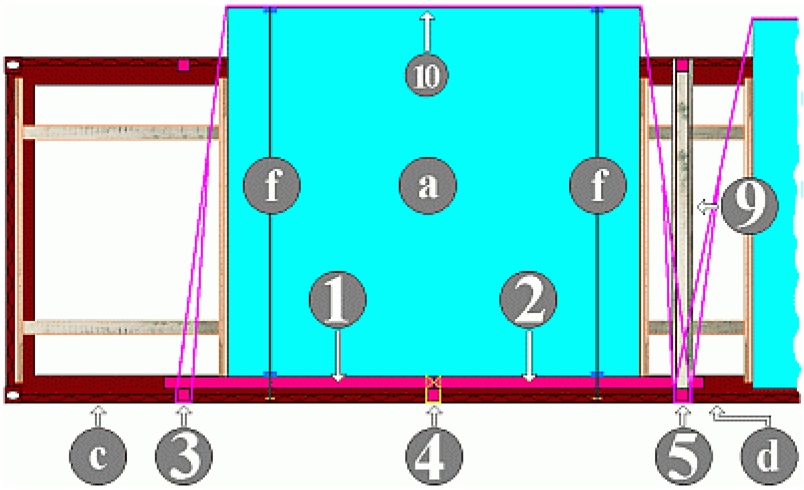
Bracing of the gaps (c), (d) and (e) and the stanchion pair at (9)

Bracing of the stanchions is intended to ensure that, when the cases are subsequently lashed at stanchion (5), the moments of resistance of two stanchions can be utilized due to the bracing (9), given that two lashings are attached to the stanchion (5).



Mutual bracing by the pairs of stanchions
Top: plan view - Bottom: end-on view

The following Figure shows securing of the left-hand case in detail:

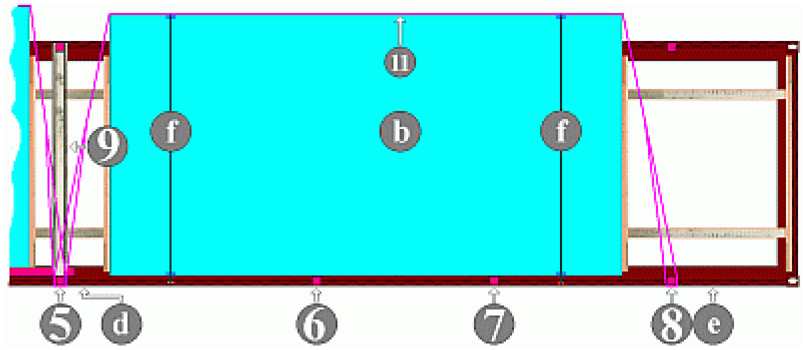


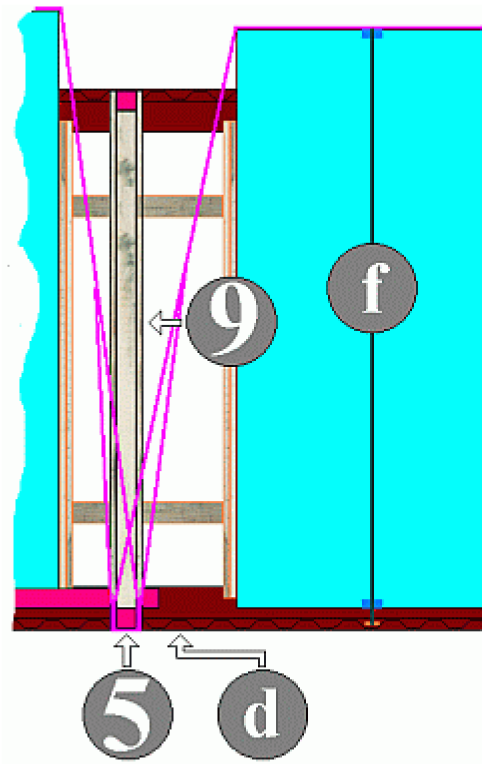
Detail: securing of left-hand case

Key to reference numerals/letters:

a	=	left-hand case
c	=	gap between case and flatrack end wall
1 and 2	=	stanchions attached horizontally lengthwise
3, 4 and 5	=	stanchions
9	=	bracing between stanchion 5 and opposite stanchion
10	=	direct lashing to hold the case laterally on the "open side"; the lashing means is passed from stanchion 3 horizontally around the case to stanchion 5
f	=	tie-down lashings

The following Figure shows securing of the right-hand case in detail:





Detail: securing of right-hand case
(left: enlargement of the left-hand part of the top picture)

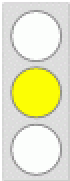
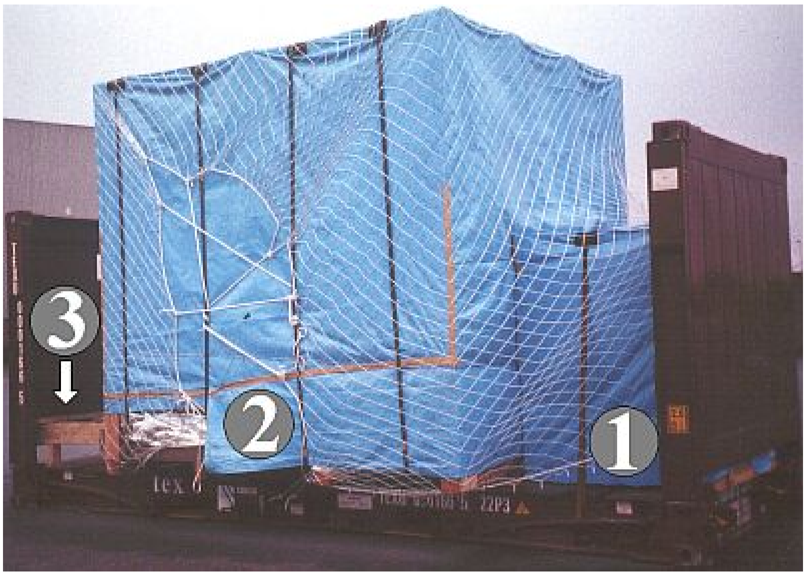
Key to reference numerals/letters:

b	=	right-hand case
d	=	gap between cases a and b
e	=	gap between case and flatrack end wall
5, 6, 7 and 8	=	stanchions
9	=	bracing between stanchion 5 and opposite stanchion
11	=	direct lashing to hold the case laterally on the "open side"; the lashing means is passed from stanchion 5 horizontally around the case to stanchion 8
f	=	tie-down lashings

5.2.8.12 Overheight and overwidth cases on flatracks, example 6

Two cases of unequal weight on a 20' flatrack

The following example is basically positive.

Securing two cases on a 20' flatrack

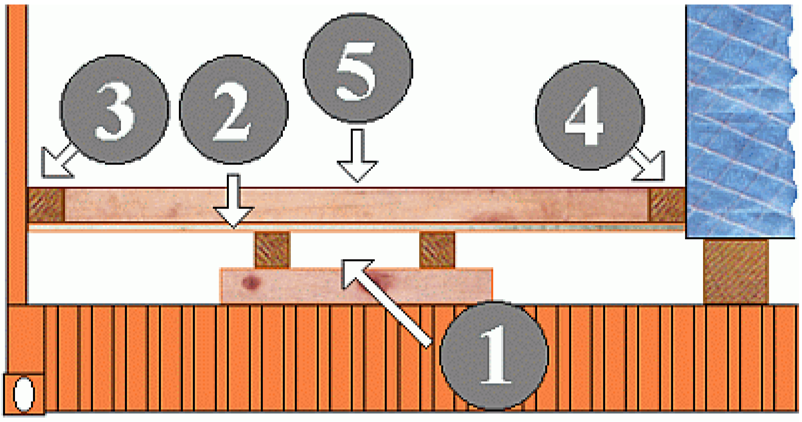
The case (1), which is neither overwidth nor overheight, is loaded tight against the end wall. The overheight and overwidth case (2) is positioned next to it. The gap between this case and the flatrack end wall is braced (3). The case's weather protection looks good - the case carries an umbrella as information mark and has consequently to be kept dry. The tear-resistant woven tarpaulin has been secured against wind with an additional net.

The steel strapping tie-down lashings all pass over edge protectors consisting of rubber tire segments, which ensures that their pretension is retained in transit. In addition, both cases have been positioned on strips of friction-enhancing material. Since case (1) had a very low mass and was clamped in place by the large case and the bracing, securing with only one tie-down lashing is tenable in this particular case.

It would have been still better if the large case had been placed on two case restraint shoes, which would have guaranteed a long-term lateral tight fit at floor level. If these had been used together with two tie-down lashings to secure against tipping, the securing arrangement could have been described as optimum.


Bracing at the end of the flatrack

The wooden bracing is technically very well made. Nonetheless, it too could be improved upon.

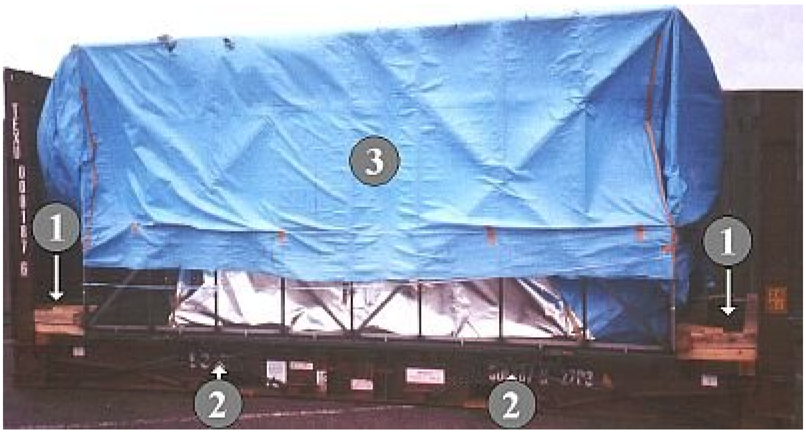


Modified wooden bracing for filling the end wall gap

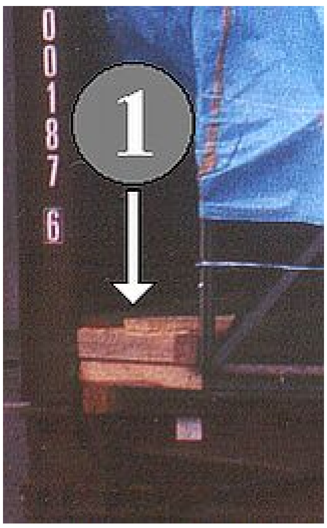
Key to reference numerals:
(1) = base made of a crossover bed of wooden members or beams laid crosswise and lengthwise
(2) = boards fitted lengthwise
(3) and (4) = crosspieces at the ends of flatrack and case
(5) = bracing members fitted lengthwise

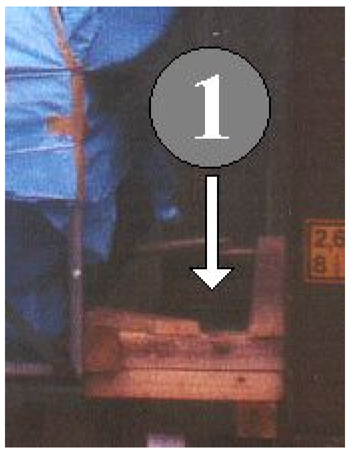
5.2.8.13 Overheight and overwidth cases on flatracks, example 7

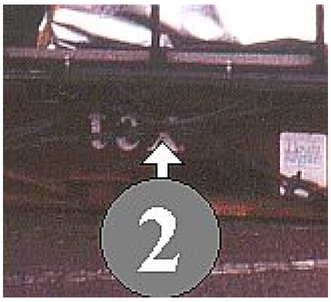
Crate made from steel angle sections on a 20' flatrack

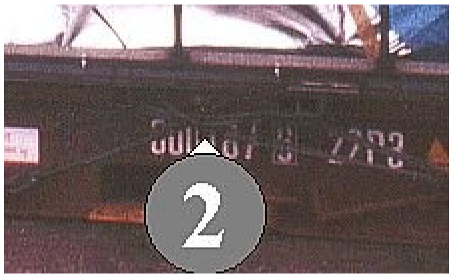


High-quality machine in a steel crate on a 20' flatrack









For clarification, the details from the picture which bear numbers 1 and 2 are shown at an enlarged scale.

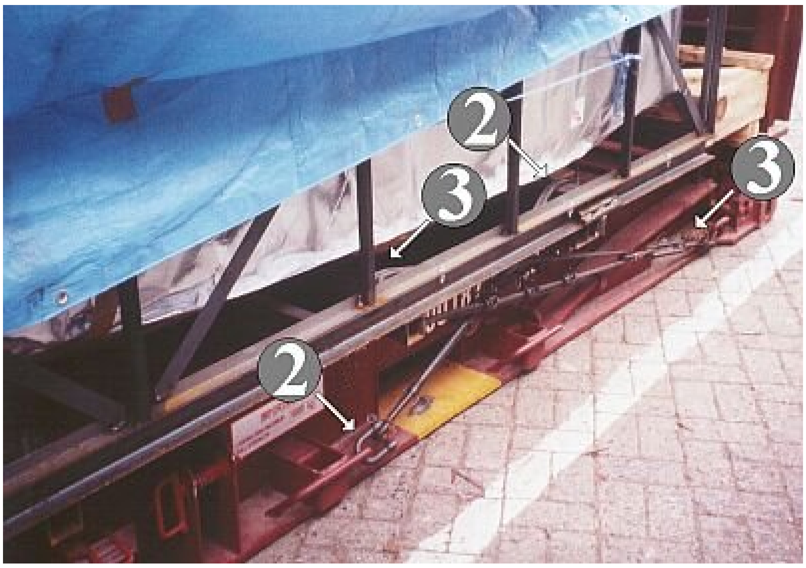
A high-quality machine heat-sealed into a sealed package to protect it from corrosion is being transported in the crate. In principle, the sensitive sealed packages should be protected by a closed container or a case. In this case, loading in a closed container is out of the question because of the dimensions of the package. Therefore, stowage in a case with sufficient load-carrying capacity is essential.

Above and right:
very small contact surface of the wooden bracing

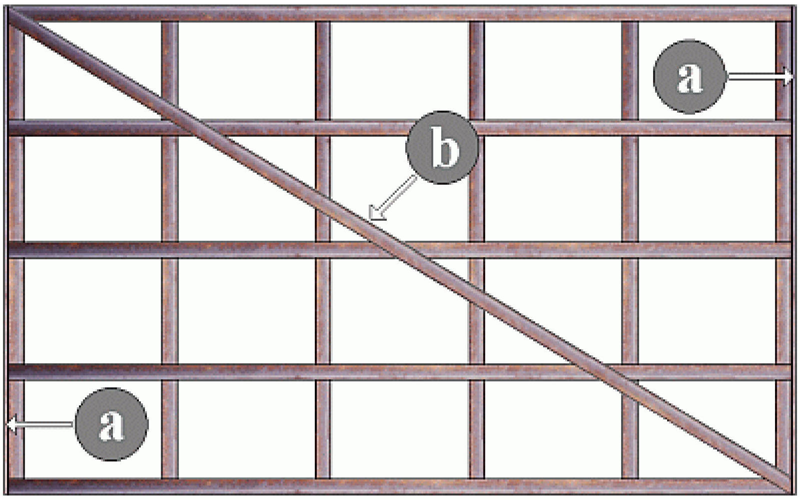
The lengthwise securing of the crate on the flatrack merits criticism insofar as only very narrow strips (1) of the steel angle sections are used as an effective area for bracing.

This may be the reason why steel wire ropes 16 mm in diameter are additionally used, together with turnbuckles and shackles, for lengthwise securing to prevent forward movement (2) and backward movement (3).

What is completely lacking is transverse securing of the crate.

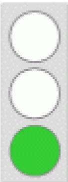


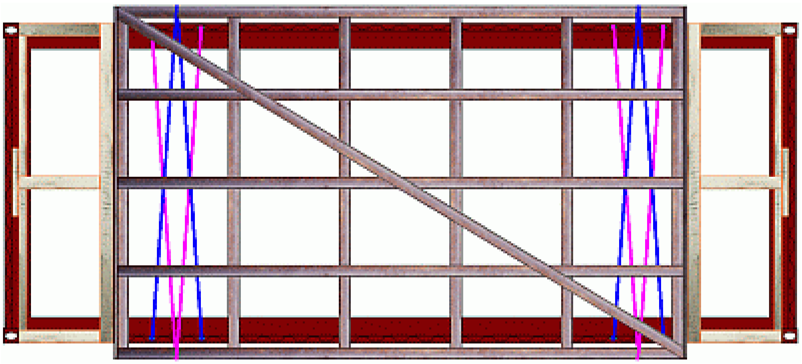
Lengthwise securing of the crate by steel wire lashings



Desirable steel crate base - plan view

So as to provide sufficiently large surface areas for bracing, flat steel profiles should be selected at the ends (a). For greater rigidity, diagonal stiffeners should be fitted (b).





Lengthwise and transverse securing of the steel crate at floor level - illustrated without the cargo for greater clarity

The steel crate may be easily braced lengthwise with wooden members, if appropriately constructed. Transverse securing may be effected at floor level by loop lashings, which are applied to the outer beams. Depending on the strength of the crate components, further loop lashings may be fitted.

Additional securing against tipping is recommended at the ends of the crate in the form of tie-down lashings or "cross lashings".

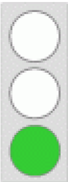
5.2.8.14 Overheight and overwidth cases on flatracks, example 8

Two crates made from steel angle sections on a 40' flatrack

This flatrack is loaded with two crates made from steel profiles. Wooden bracing has been positioned against the end walls to provide lengthwise securing. Lateral securing was provided for the longer crate in the form of four tie-down lashings and for the shorter crate in the form of two tie-down lashings made from steel wire ropes 16 mm in diameter.

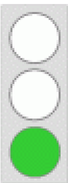
Waste of materials due to nonuniformity of lashings

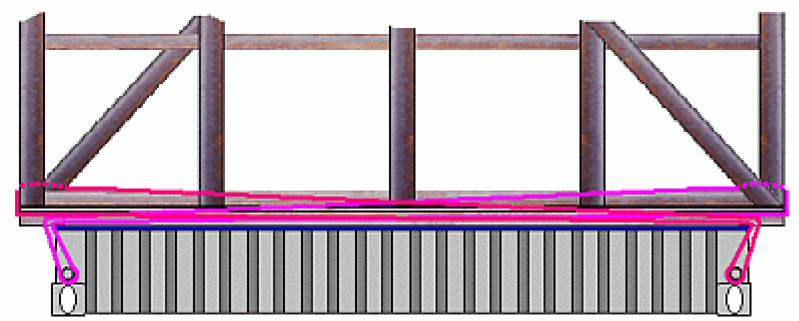
With a 16 mm steel wire rope, a maximum securing load of at most 10,240 daN can be achieved per single run. These values are reduced as a result of small deflection radii, using fewer than 4 wire clips, angles of spread (such as the 120° here) and similar factors. The lashing points probably have a maximum securing load of approx. 3,000 daN. A not inconsiderable amount of material has consequently been wasted. When selecting the lashing materials, the lashing personnel should have ascertained the maximum securing load of the lashing points.



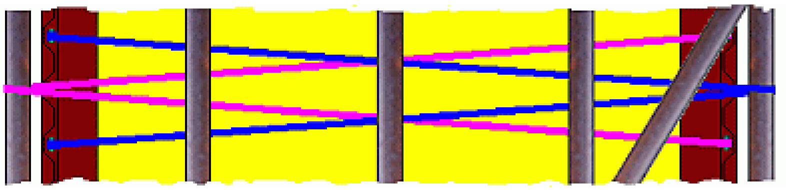
Expert bracing at the ends

The bracing against the corner protectors of the flatracks does not merit any criticism. The use of the small board at (1) constitutes a minor defect and reduces the effective cross-sectional area of the bracing a little.



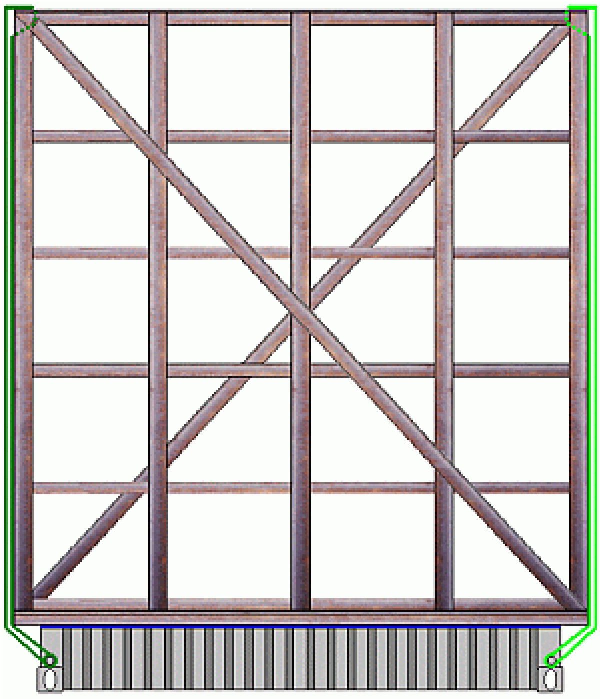


Transverse securing using loop lashings at floor level - end-on view



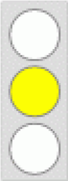
Transverse securing using loop lashings at floor level - plan view

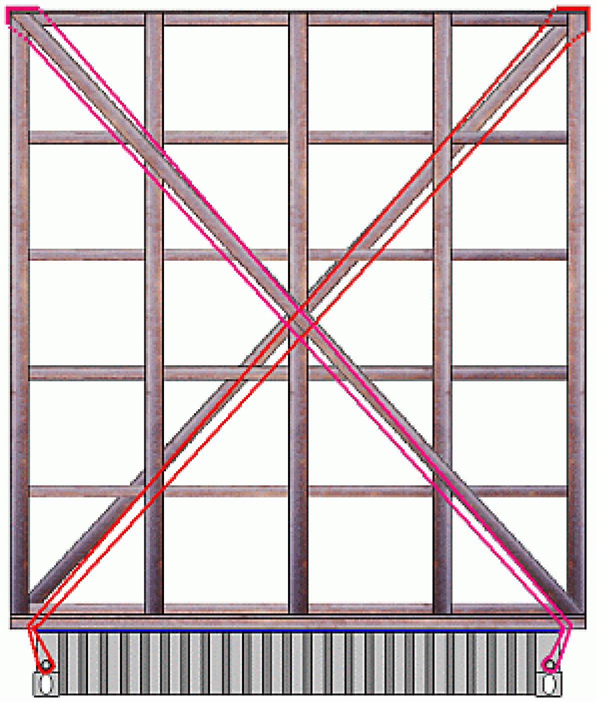
The most favorable force components for good transverse securing can be achieved by loop lashings. The maximum securing load of the lashing wires, lashing belts or other securing materials can be doubled by positioning the ends at separate lashing points. By laying friction-enhancing materials under the steel crates, the total securing forces required can be reduced.



Direct lashing against tipping

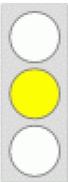
Rather than tie-down lashings, direct lashings should be used against tipping. Depending on the strength of the crates, these do not necessarily have to extend as far as the upper side rails, but can be attached lower down.





Unfavorable securing using diagonal lashings (cross lashings)

Cross lashings as shown have both corresponding transverse and vertical components. Nevertheless, the other methods described above (for separate application) are preferable to this combined method.



Diagonal lashings are virtually incapable of preventing tipping.

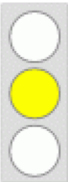
The Figures show that cross lashings are virtually incapable of preventing the shipping packages from tipping.

5.2.8.15 Overheight and overwidth cases on flatracks, example 9

Crate made from steel angle sections on a 20' flatrack

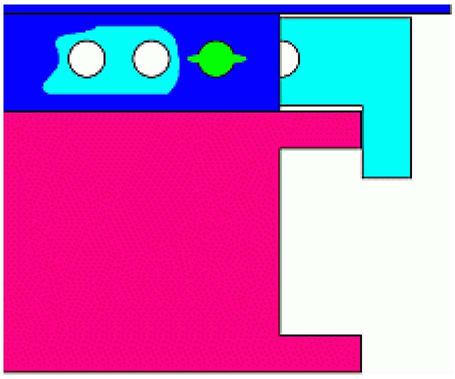
Inadequate transverse securing of a steel crate

Here too, transverse securing is provided solely by tie-down lashings. A negative feature is once again the nonuniformity of the 16 mm thick steel cable lashings. Another unfavorable feature is that all the turnbuckles are located on one side. One positive feature is the use of automobile tire segments as edge protection and to provide additional elasticity.



Left and below: lengthwise bracing in need of improvement

The lengthwise securing made from squared lumber is not as good as it could be. The wooden members are not applied against the parts with the best loading capacities, which in this case would be right at the bottom, where the crate of steel profiles is at its strongest. The unilaterally overhanging stowage arrangement adopted is cost-effective, as it allows one less slot to be used.



Transverse securing option provided on crate

Since steel profile crates are regularly used for carriage, a transverse securing option could be provided on the structure by the manufacturer. The bottom cross members of the crate often consist of rectangular tubing. These could be prepared in such a way that telescopic tubes with welded-on angles can be inserted and secured with pins, such that the angles grip with a tight fit over the outer edges of the flatrack. With such crates, only means providing lengthwise securing and securing against tipping have to be fitted, which is cheap to achieve.

5.2.8.16 Overheight and overwidth cases on flatracks, example 10

Cases, some overheight and slightly overwidth, together with an overwidth plant part on a 40' flatrack

Export cargo on a 40' **flatrack**

The left-hand case is approx. 10 cm from the end wall of the flatrack and is secured with three tie-down lashings, the plant part and the case packed to the right thereof being secured with two tie-down lashings. The smaller wooden case is blocked into the lengthwise bracing.

Inadequate securing of the long wooden case

The gap at (1) could easily have been filled with 10 cm x 10 cm squared lumber. Steel strapping tie-down lashings tensioned over wooden edges (2) cut in, lose their pretension and are then only capable of providing a limited degree of securing. Securing with case restraint shoes at floor level is advisable. The steel strapping tie-down lashings could remain as securing against tipping, if segments of rubber tire were laid under them. Heavy-lift steel cornerpieces can prevent cutting into wooden members. However, these measures do not alter the fundamental disadvantage of steel strapping, i.e. its low elasticity.

Inadequately secured plant part

The two tie-down lashings alone cannot secure the cargo in the long term, given that steel is here stowed on steel. The plant part is freely movable sideways in the tie-down lashings.

The plant part should as a bare minimum have been placed on friction-enhancing material, or at the very least wooden boards.

Right and below:
possible securing
using loop lashings

Loop lashings have already been suggested so often in this section that this option should generally be considered and assessed for possible ways of implementing it. However, another securing method is feasible:

Since the base frame of the plant part projects over the sides of the flatrack, internal bracing is an option. For this purpose, short steel profiles corresponding to the stanchion cross-section are inserted into the stanchion pockets. If the flatrack has very low stanchions, these may of course be used.

Bracing against steel profiles
inserted into the stanchion pockets

Producing internally acting wooden bracing
- steps 1 to 3

Wooden beams, for example 6 cm x 8 cm beams, are laid on their edges to the left and right of the inserted steel profiles or stanchions (1) and attached to the flatrack floor (2). The length of the beams must be matched to the internal dimensions of the structure to be secured, but they do not have to be cut absolutely exactly to size, since they are just auxiliary wooden members. A squared lumber member (3) cut precisely to length is fitted onto each pair of beams between the steel profiles or stanchions and fastened to the beams. Each squared lumber member is intended to allow utilization of the strength of two profiles or stanchions. This step can be omitted if the cargo items are light.

Producing internally acting wooden bracing
- steps 4 or 5

Squared lumber pieces (4) are fitted precisely in the crosswise direction or squared lumber is fitted in the lengthwise direction (5) between the internal edge of the plant part and the external edge of the steel profile or stanchion and in each case fastened to the beams beneath.

The squared lumber at (4) is loaded against the end grain, i.e. end on to the grain. A maximum securing load of 400 daN per square centimeter of effective supporting surface area may therefore be expected. The squared lumber at (5) is loaded perpendicularly to the grain. In this case, an effective supporting surface area of only 30 daN per square centimeter can be expected.

Wooden case secured inadequately in the
crosswise direction

The statements already made in relation to the longer case also apply to securing of this taller case.

Lengthwise case securing in need of improvement

Positive comments first: The bracing for the tall case has been fitted in such a way that the plate action of the sides of the case (a) is exploited. The small case, positioned in the stowage gap, is only secured by wooden fixings (b), i.e. planks nailed on crosswise. The diagonal boards serve to stabilize the structure.

Expertly braced cases

The tall case is braced by horizontal wooden members, which lie on the transverse boards of lattices. The lattice in front of the case consists of two vertical squared lumber members and three transverse boards, while the lattice in front of the flatrack end wall is made from two vertical and three transverse boards.

Securing of the small case

The small case is secured by building a small lattice from two vertical and two transverse boards and positioning it against the case end wall. Squared lumber is fitted between this lattice and the one against the flatrack end wall. To provide lateral securing, squared lumber is additionally threaded through and fitted next to the case.

5.2.9 Palletized cargo

The advantage of correctly palletized cargo is that cargo handling can be mechanized and, provided the pallets fit the container, securing can largely be dispensed with. Provisos are that the pallets are sensibly packed, the dimensions of the packed pallets in the lengthwise and crosswise directions each correspond to fractions of the internal container width, length and height and the pallets are stackable. If these conditions are met, and strictly speaking only if they are, can cargo be described as "fully palletized". Many cargo handling and packing companies offer special terms for fully palletized cargoes.



Packing a container with palletized cargo without interlayer dunnage

If the packages are strong enough, they can be stacked on top of one another without interlayer dunnage.



Packing palletized hazardous materials with interlayer dunnage

If the pallets or goods are more sensitive, interlayer dunnage made of lumber, hardboard, chipboard or similar materials should be put in place to distribute pressure.




Palletized cargo - incorrect **Palletized cargo - correct**

Even small gaps and slightly sloppy packing methods can cause the packages to cave in and goods to be damaged. If the pallets delivered are neatly packed and interlayer dunnage is used for packing, such shortcomings can be prevented. Even the smallest gaps must be filled, be it with wooden boards, airbags or, as here, with old pallets.



Packing a 40' container with palletized cargo


Deficiently packed palletized cargo


The shipping packages are not well packed. Interlayer dunnage is essential with the type of pallet base used. The gaps left are too big.

Packing gaps = packing deficiencies

Every packing gap constitutes a potential risk. Damage can only be prevented by absolutely compact stowage.

The greatest deficiencies which occur when packing palletized cargo are that the pallets are not properly packed and the pallet dimensions are not conformed to the containers used. A few examples follow:

Who could load pallets like this without having to put an unusually large amount of effort into securing them? At the same time, such pallets are in contravention of the dangerous cargo regulations and the CTU packing guidelines. The general introduction to the IMDG Code reads.:

For the purposes of this Code, a "unit load" means a number of packages that are:

1.) *placed or stacked on and secured by strapping, shrink-wrapping or other suitable means to a load board such as a pallet; or;*
2.) *placed in a protective outer enclosure such as a pallet box; or;*
3.) *permanently secured together in a sling.*

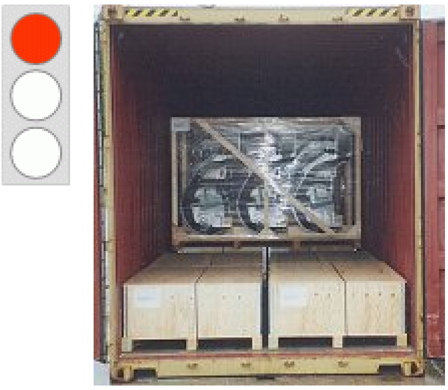
10.18.2 packages that contain hazardous goods, that are permitted to be transported in accordance with the code, may only be transported in unit loads if the following conditions are fulfilled.
10.18.2.1 It may occur that the packages in a unit load will need to be separated. In this event, it must be ensured that the individual packages can be handled safely.
10.18.2.2 The unit loads should be compact, have as regular a form as possible, and for the most part, vertical sides. The top of the unit load should be level. It must be possible to stack the unit loads. They must be constructed and secured in such a way that it is unlikely that the individual shipping packages can become damaged.
10.18.2.3 The unit loads must be sufficiently strong to withstand repeated loading and stowing operations and they must be able to bear unit loads with a similar specific mass which are stacked on them to a height commonly occurring during transportation.

What conclusion would one draw from a comparison of the text of the regulations with reality?

The CTU packing guidelines contain a similar comment under point 4.2.8:

If dangerous cargoes are palletized or otherwise unitized they should be compacted so as to be regularly shaped, with approximately vertical sides and level at the top. They should be secured in a manner unlikely to damage the individual packages comprising the unit load. The materials used to bond a unit load together should be compatible with the substances unitized and retain their efficiency when exposed to moisture, extremes of temperatures and sunlight.

It may be noted also with regard to these requirements that there is general ignorance of the law and of transport safety.



Unsecured cargo

Secured cargo

Although this cargo is not palletized, it resembles palletized cargo from the point of view of base and overall treatment. As is clear, appropriate compact stowage can be achieved without much effort.

5.2.10 Paper rolls

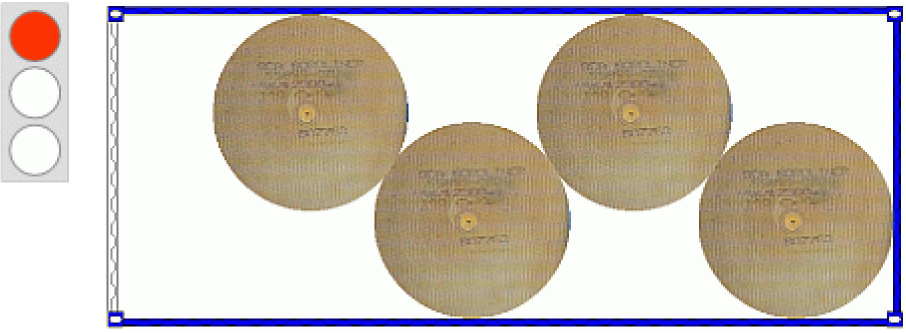
5.2.10.1 Paper rolls, vertical axis

Examples of paper and other roll-shaped cargoes

In the case of newsprint, it is important for the container floor to be absolutely clean. Even the smallest amount of dirt from the floor could bring a printing line to a standstill if it becomes pressed into the rolls. Kraft paper or the like is recommended as floor dunnage. Friction-enhancing materials may also be used under the load, corresponding at least to the cross-sectional areas of the rolls.

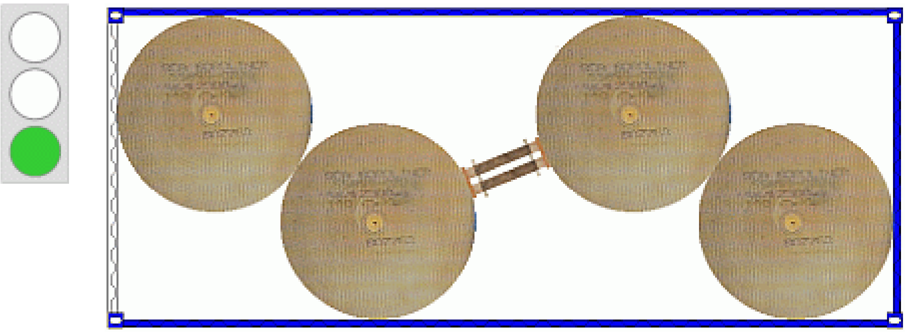
Compact packing for roll diameters of 1,300 mm

Packing of paper or kraftliner rolls is problem-free, if the diameters allow absolutely compact packing, as is the case here for rolls with a diameter of 1,300 mm.



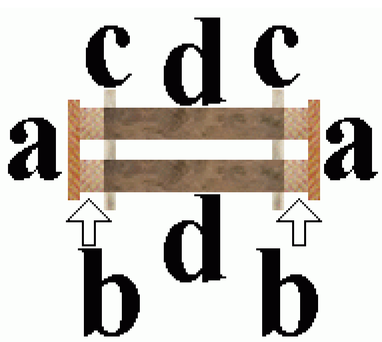
Gaps left in the case of roll diameters of 1,500 mm

Where rolls have diameters of, for example, 1,500 mm, gaps are left. For reasons of load distribution, these must not be left in the door area, as here.



Bracing of a gap for roll diameters of 1,500 mm

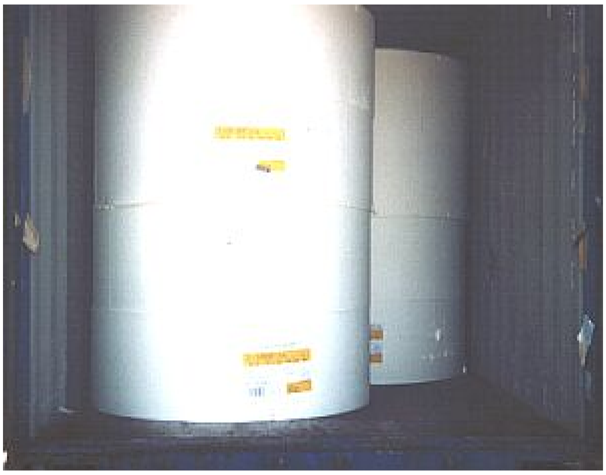
The first two rolls are loaded The third is placed in the position of the last roll and the semicircle of the roll which points forward and to the middle is traced on the floor with chalk. Roll three is then brought into its final position. Wooden bracing is applied and fixed between rolls two and three. Roll four completes the packing operation.



Wooden bracing for bracing rolls - plan view

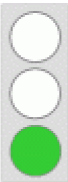
The bracing consists to the left and right of a wide board (a), to each of which two beams (b) have been nailed vertically. Transverse boards (c) or beams are nailed to these beams at quarter and three-quarter height of the roll, and serve as supports for the bracing members (d).

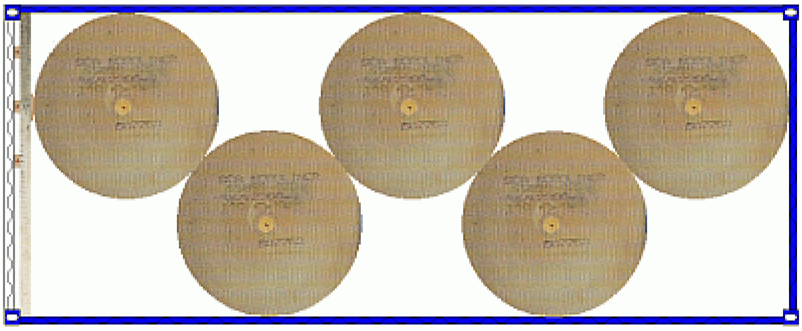
To ensure that the bracing does not change position, it is essential for it to be fixed, but how this is done depends on the conditions in the container.



Small gap in the door area with roll diameters of 1,425 mm

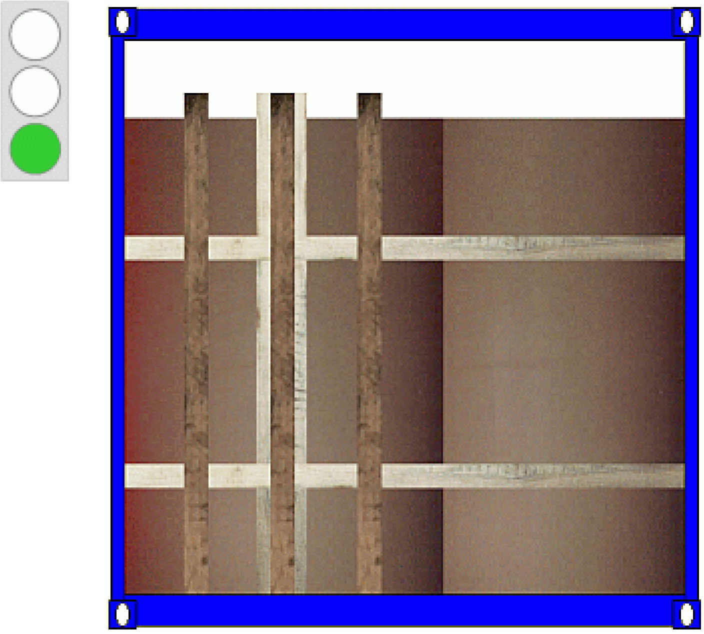
Even a relatively small gap should be closed, while absolutely avoiding point loads.



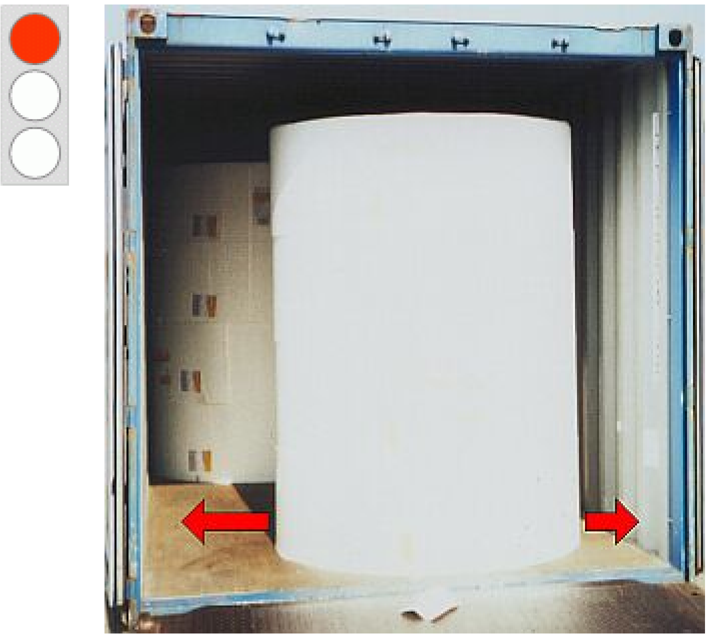


Bracing of a gap in the door area - plan view

A board is positioned vertically against the center of the roll(s). Squared lumber is fitted transversely between the container corrugations at quarter and three-quarter height, and if required also in the middle. Boards, beams or squared lumber are fitted in perpendicularly thereto in such a way that the remaining gap is filled as far as the door leaf.

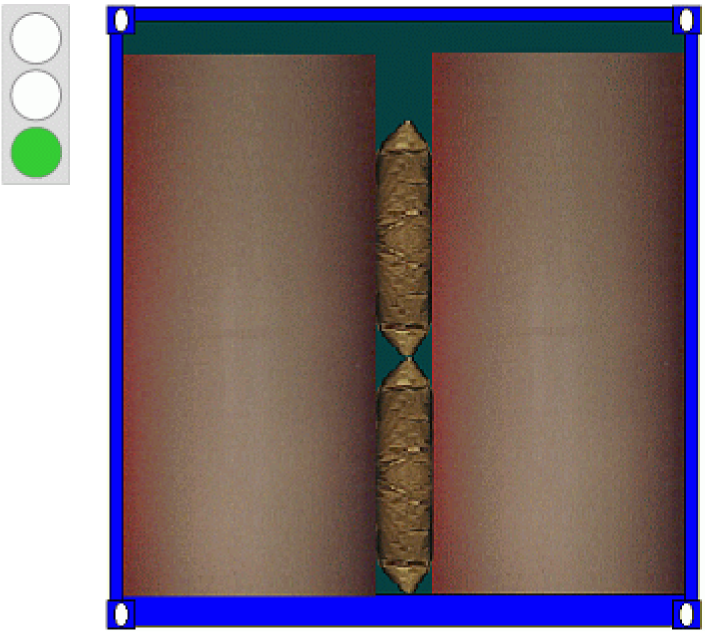


Bracing of a gap in the door area



Inadequate packing of paper rolls

Under no circumstances should gaps be left on both sides, unless they are filled in.



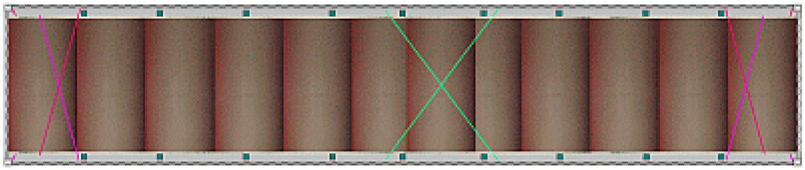
Paper rolls secured with airbags - end-on view

Vertical rolls can be secured cheaply with airbags if the gaps left are narrow, e.g. approx. 20 cm.

5.2.10.2 Paper rolls, axis lying crosswise

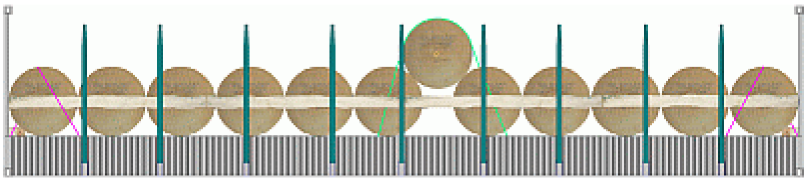
Rolls could also be stowed with their winding axes lying crosswise but this makes packing and unpacking far more difficult. The method is not therefore to be recommended.

Kraftliner rolls on flatracks with stanchions are an exception. Both packing and unpacking and securing are then cheap to implement.



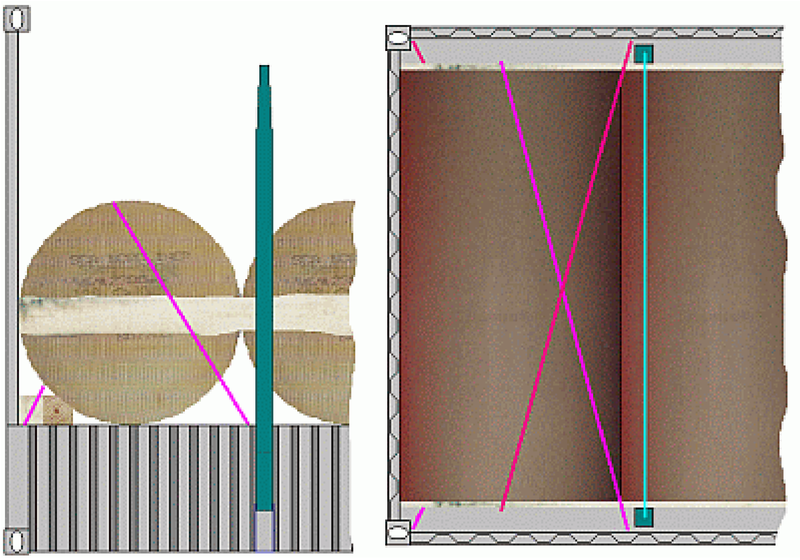
Kraftliner rolls on a 40' flatrack - plan view

Because of their dimensions, six rolls are loaded from the left-hand end wall and five from the right-hand end wall towards the middle and the twelfth roll is positioned in the cantline.



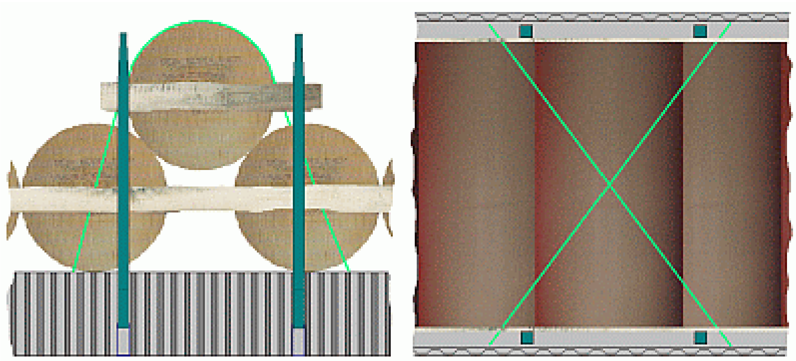
Kraftliner rolls on a 40' flatrack - side view

Crosswise, virtually all the rolls are secured with a tight fit by filling the small gap between them and the stanchions with boards attached at the level of the roll eye. All the stanchions are lashed together (this detail was omitted from the overall views). To relieve the end walls, the outer rolls are propped by crosswise wedge beams and braced against the end walls.



Securing of the outer rolls - side view and plan view

Crosswise, the outer rolls are secured with loop lashings, which pass around the securing boards.

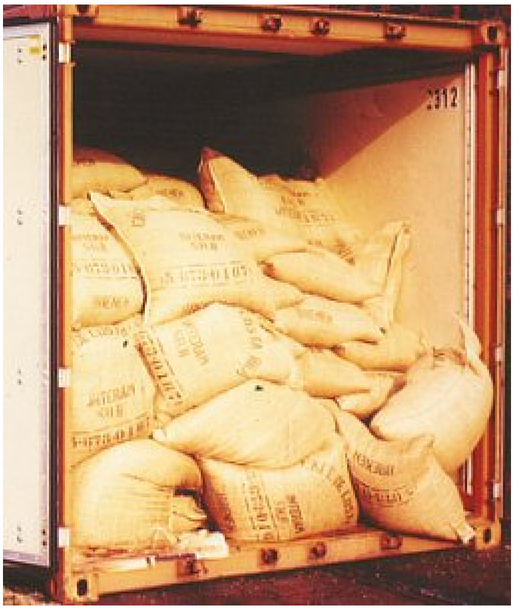


Securing the roll in the cantline - side view and plan view

The roll lying in the cantline is also secured by means of boards fixed to the stanchion and overlashings. Strips of friction-enhancing material are positioned at the points of contact with the rolls packed underneath.

5.2.11 Bagged cargo

Some information has already been provided about bagged cargo and the various packing methods in the sections on packing and basic stowage methods. In general, packing patterns should be used with which the containers can be packed with the fewest possible gaps and to a uniform height.



Import container with coffee bags

An example of a chaotic "stowage pattern". The stow was not anchored.

Jumbled plastic bags

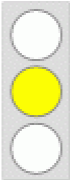
In neither of the cases shown had the cargo yet suffered any damage, but the high additional costs of additional manual labor must be borne in mind.

In the light of these two pictures, it is worth taking a look at the CTU packing guidelines, which state in point 5, which provides advice on receipt of CTUs:

> *5.1 When receiving a CTU, the receiver should ascertain that the unit is externally in good condition and without damage. If there is any damage, the receiver should document and notify it as appropriate. Specific attention should be paid to damage that may have influenced the condition of the cargo within the unit. If the receiver detects any damage during the discharge of the unit, this should be documented and notified as appropriate. If a package containing dangerous cargoes is found to be so damaged that the contents leak out, the immediate area should be evacuated until the hazard potential can be assessed.*
> *5.2 Persons opening a CTU should be aware of the risk of cargo falling out. Doors, when opened, should be secured in the fully opened position.*

5.2.11.1 Bagged cargo, unpalletized

It is essential to load unpalletized bagged cargo in a compact manner. Plywood or aluminum containers with a plywood liner are to be preferred to corrugated steel containers. When inspecting fitness for loading, one very important point is to check for the absence of pointed or sharp-edged parts which could damage the cargo; even small splinters of wood on the container floor, residues of old cargo securing material, protruding nail ends or the like may cause such damage. If such sources of damage cannot be eliminated, they should be carefully covered over. It is often recommended to pack bags in a crisscross arrangement. This ensures good stability within individual stacks, but not an interlocking stow. Labor costs are higher because the bags have to be rotated or alternately positioned in different directions.



Non-interlocking stow:
alternate longitudinal and crosswise packing

However a cargo is packed, an interlocking stow must be created in some way. This can be achieved by including "anchors" in the stow. These anchors may take the form of wooden dunnage boards, walking boards, plywood sheets and similar materials inserted as interlayer dunnage. In the case of bags with very smooth surfaces of plastic or plastic-coated paper, anchors may also consist of grayboard, kraft paper or the like. Application of antislip sprays may also be of assistance.

Absence of anchors promotes bag slippage.

In this case, the bags were simply stacked in a "tower" without any interlayer dunnage as the anchor. No interlock means no stability.

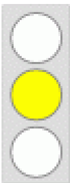
5.2.11.2 Bagged cargo, palletized

Excessively large gaps in the stow

These small gaps are enough for the bags, when exposed to the movement of the sea, gradually to work free under the relatively loosely shrink-wrapped cover and be abraded at the bottom on the pallet boards. If some of the bags are damaged and "bleed", they will create ever more free space which may result in damage to the remainder of the cargo. The gaps are there because of the dimensions of pool pallets. With dimensions of 800 mm x 1,200 mm, one pallet loaded crosswise and another longitudinally will together occupy a width of 1.2 m + 0.8 m = 2.00 m, while the internal width of the container is approx. 2.34 m, so leaving a gap of 34 cm.

Unacceptably large gap in the stow and non-flush packed pallets

Bigger gaps mean an even bigger risk. It is favorable if pallets are adapted to the container door dimensions and virtually match the internal dimensions. So that, during packing with forklift trucks, bags on any already loaded pallets are not damaged by pallets which have been lifted up for subsequent loading, it is worthwhile placing walking boards or hardboard sheets vertically between the pallets.



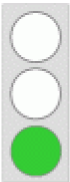
Without separation by walking boards

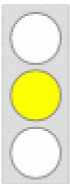

With separation by walking boards

Some of the bags are so slackly filled that the lower layers have already been squashed. When packed in corrugated containers, such pallets can cause problems during unpacking as they may adapt to the shape of the corrugations, making them difficult to unpack.

5.2.11.3 Big Bags

The same rules apply to Big Bags as to all other goods. It is essential to avoid gaps in the load as this is the only way to ensure that damage will not occur in transit.





Exemplary container packing with Big Bags

If packing is continued in the same manner and proper bracing is provided in the gaps in the door area, this will be a copybook example of packing. Such compact loading is only feasible and a positive example because the bag fabric is sufficiently strong for the Big Bags not to be able to conform to the corrugations. The amber traffic light is intended to signify "Caution" because, with a softer fabric, hardboard or similar material should be placed against the side walls to stop the Big Bags from meshing with the corrugations in the walls.



The wooden **interlayer dunnage** is not enough on its own.


No comment!

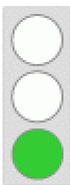
5.2.12 Cartons

Other Sections have already addressed cartons and how to load them in some detail, so this Section will provide only a few notes.

The loading area should be filled as completely as possible. When the orientation of the corrugations in corrugated board can be determined, it should be taken into account during loading, if possible being kept upright. If this is contradicted by handling symbols such as "Keep upright", the symbols should be obeyed. As early as during preliminary planning, it is possible to calculate the stacking height at which it is possible to achieve a uniform cargo block over the entire length of the container. Depending upon the strength of the cartons, interlayer dunnage may have to be used. In the case of very weak cartons, the interlayer dunnage may be supported like a "false deck". If gaps occur during packing, they must be filled immediately as it will not subsequently be possible to reach the gaps without damaging the cargo. Stacking in an interlocking pattern is sometimes recommended. In the present author's opinion, this is inadvisable because higher levels of strength are achieved if the outsides of the cartons are arranged perpendicularly one above the other. An interlocking stow is better achieved by using anchors of kraft paper, grayboard or similar material.

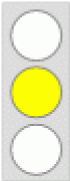
Any remaining gaps in the door area can be filled with wooden lattices and squared lumber bracing against the corner posts.






How it actually was ...

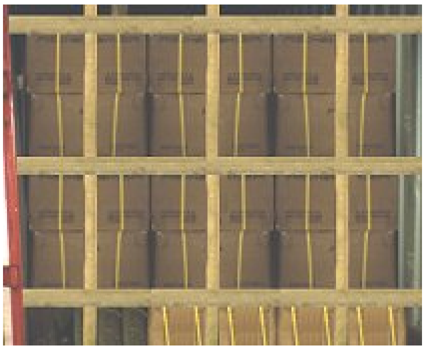
... and how it could have been!



Manual packing of cartons and trays

Even with "big cartons" the gaps must be filled.

Compactly packed container



Securing in the door area with a lattice

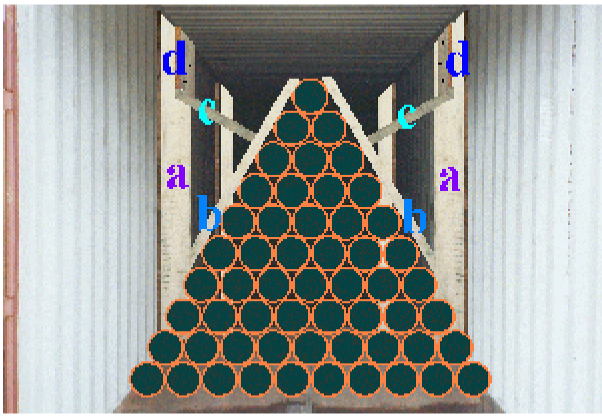
5.2.13 Pipes, nonmetallic

The basic stowage methods section has already described how to pack and secure pipes with sockets. The metallic pipes examples included tips for packing and securing socketless pipes. Nonmetallic pipes, whether made from ceramics, plastics or other materials, can be secured very effectively in the sideways direction with loop lashings. Lattices can be used in the lengthwise direction. Neither securing method exerts harmful pressure on the pipes to be carried. Only once inertia forces come into play due to acceleration do the securing means become effective and exert forces on the cargo.

The following example is simply meant to demonstrate that even sensitive pipes can be secured with lumber, in particular when a container lacks lashing points.

Securing a stack of pipes with boards and beams

This method is relatively simple to implement. For clarity's sake, only the front part is drawn in.

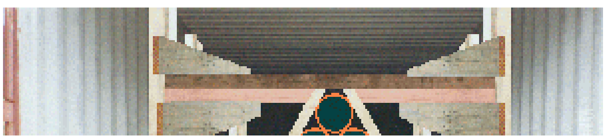


Securing with boards and beams - key

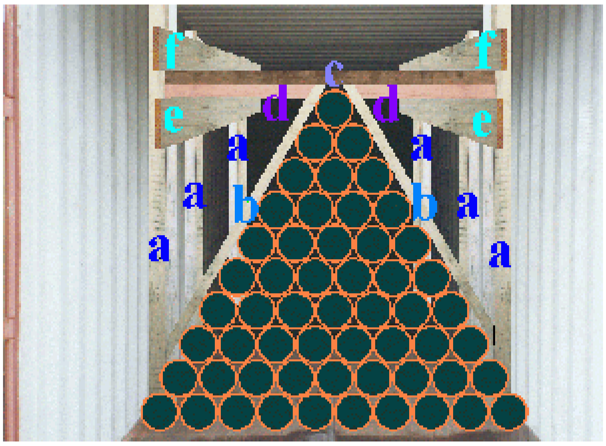
Boards (a) are arranged in pairs against the container side walls before the pipes are placed inside. Once the pipes have been packed, squared lumber beams (b) are laid on the sides of the pipe stack in such a manner that the cut bevels are wedged against the boards. The wooden securing members are fixed in place using further beams (c) and nailed-down board ends (d). Additional longitudinal boards or wooden X-bracing, which may be used to reinforce the overall structure, have not been drawn in.

The following Figure shows another possible design:

Securing a stack of pipes with squared lumber, beams and boards



In order to clarify the order in which the securing operations are carried out, the same diagram is given below with an added key:



Securing with squared lumber, beams and boards - key

Before loading, squared lumber members (a) are arranged in pairs against the container side walls, either fitted exactly into the corrugations or fixed with driving wedges. Depending on their mass, once the pipes have been loaded, squared lumber members or beams (b) are placed on the sides of the pipe stack and wedged against the squared lumber uprights with their beveled ends which have been cut to size. In order to fix these wooden members at the top, a squared lumber member (c) with two wooden members (d) nailed on underneath is in each case fitted between the squared lumber uprights in such a manner that the wooden members (b) are held together at the top. The boards (e) and (f) are provided in order to fasten the members (c) and (d) together and they moreover provide additional stability to the entire structure. Some of these operations can, indeed should, be carried out outside the container or before packing.

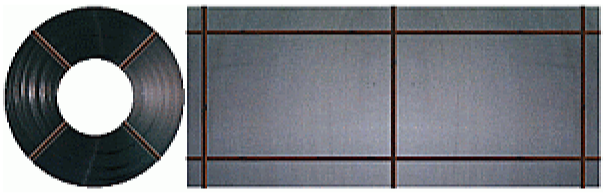
5.2.14 Steel and metal cargoes

5.2.14.24 Slab-like steel parts on a flatrack
→ 5.2.14.25 Heavy plate and sheet packages on flatracks
5.2.14.26 Sheet packages in box containers
5.2.14.27 Ingots in box containers

5.2.14.1 Steel coils: general information

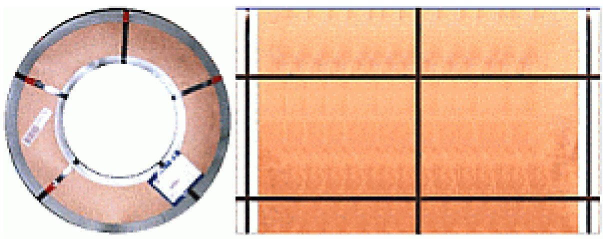
Coils: general information

(Steel) coils are rolls of steel sheet, which are primarily classed as either hot-rolled strip or cold-rolled strip. Slit strip coils with a shorter winding axis are produced from wide strip in special slitting plants; slit strip coils may be transported individually or consolidated into bundles. Slit strip coils are often supplied on wooden sleds or skids with the winding axis vertical. Other coils may, however, also be supplied for shipment fastened onto skids with the winding axis vertical or horizontal. Coil remnants are lower grade goods and are often only loosely wound.



Hot-rolled strip, only bundled

Hot-rolled strip is almost always shipped unpackaged, only being held together with a variable number of steel straps. While attention must be paid to protecting such goods from damage also with regard to cargo securing measures, the risks are not so great for hot-rolled sheet. Edge protection, for example, is not so important. The situation is quite different with cold-rolled sheet, which has almost always been pretreated and is very sensitive. Transport risk varies as a function of the mode and route of transport and such products are often provided with different grades of packaging as a consequence.



Cold-rolled sheet in packaging of special paper, hardboard and folded sheet metal edge protectors

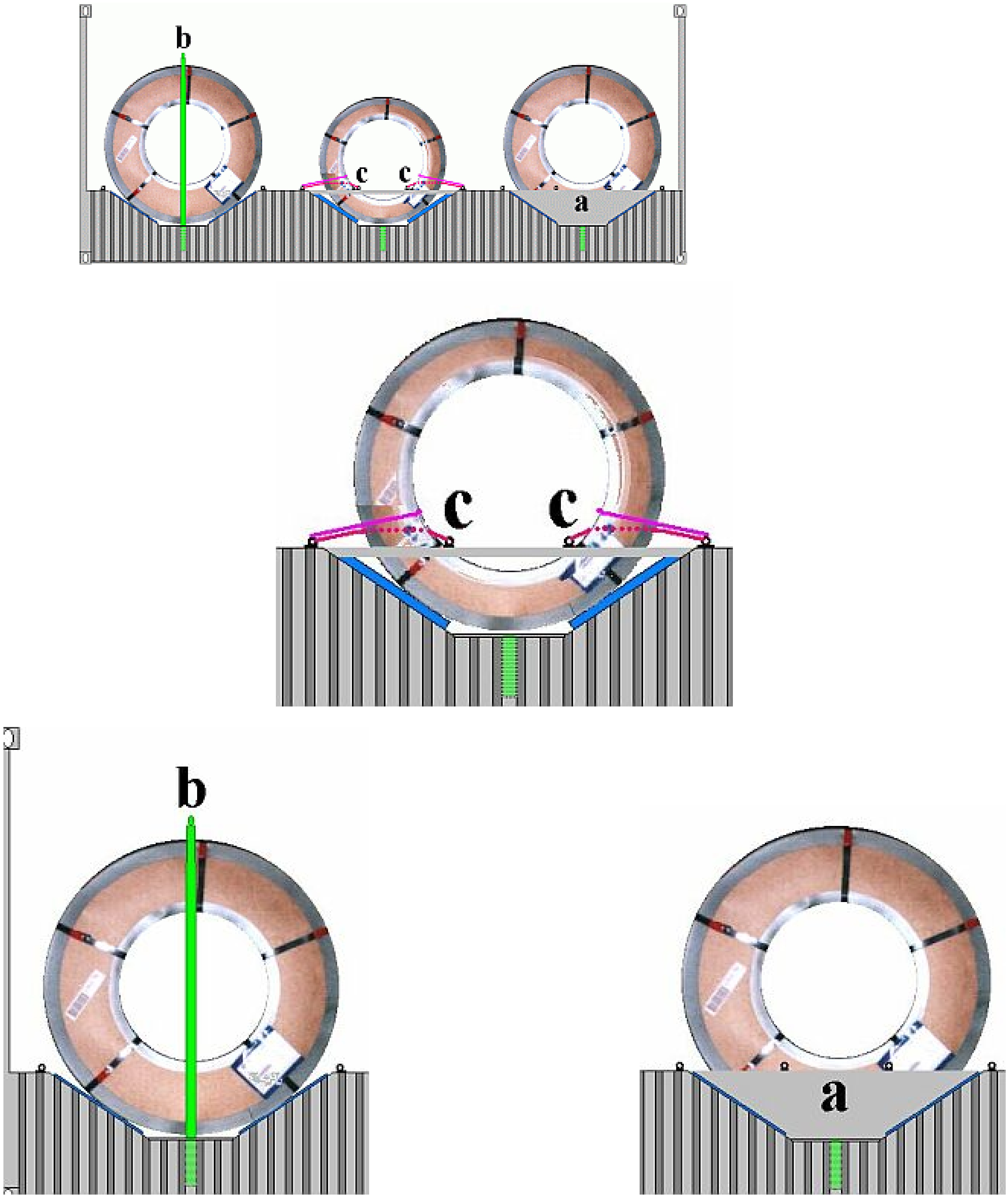
Special container for coil transport

Shipowners will always tend to prefer to carry containers which are as versatile as possible. From the standpoint of cargo securing, i.e. disregarding climatic and chemical transport risks, coils are best shipped on coil containers. These are flatracks which have special troughs for coils and, in some cases, also additional cargo securing equipment.

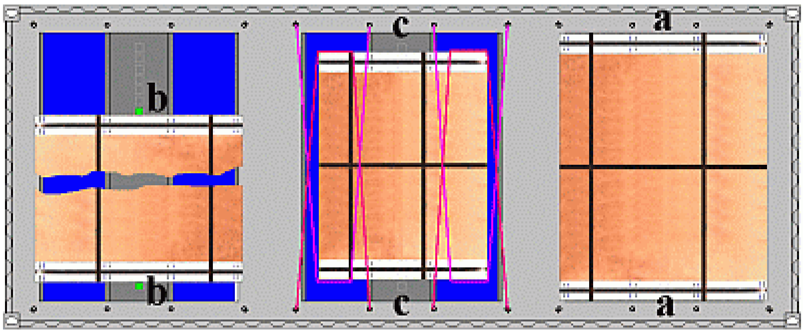
In conventional coil containers, the coils are carried with the winding axis lying crosswise. So that these containers do not have to be used solely for carrying steel coils, the troughs can, or could, have covers making it feasible to a limited extent also to carry other goods on these flatracks.

5.2.14.2 Coils on coil containers

Coils loaded on a coil container

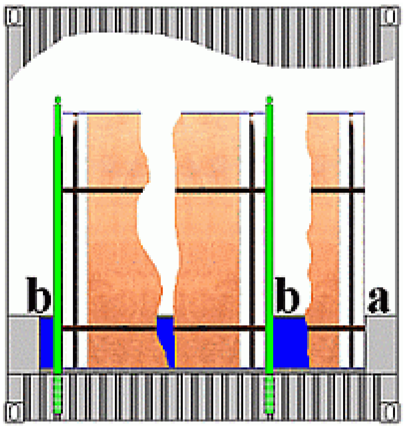


Top and selective enlargements below:
Coils loaded on a coil container - side view

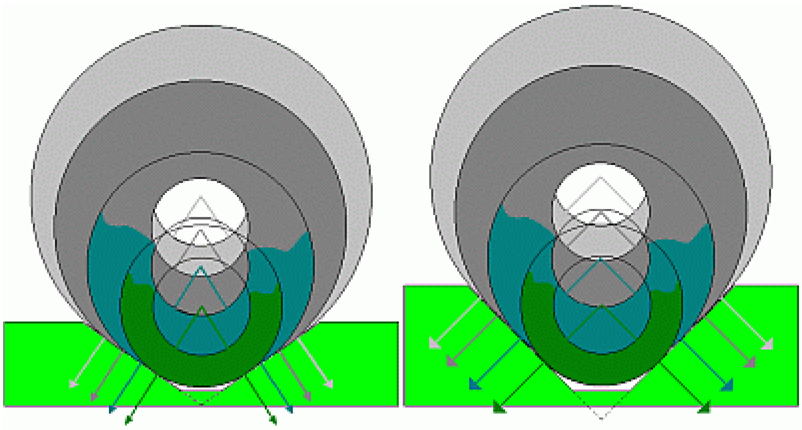


Coils loaded on a coil container - plan view

Depending on their dimensions, coils may rest directly against the sides of the coil trough (a), be secured by stanchions (b) or be held in position by loop lashings passed through the coil eye (c).



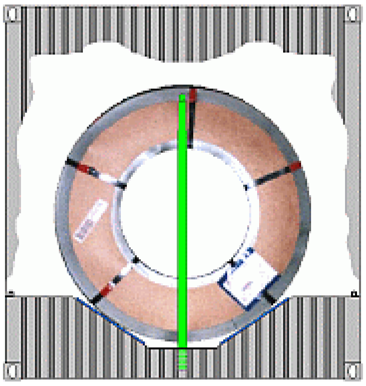
Coils loaded on a coil container - cross-section



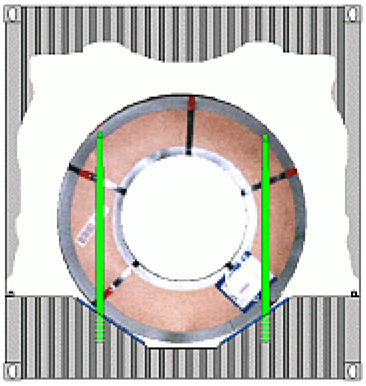
Coils of various diameters in a 35° and 45° coil trough

The flank angle directly determines the degree of securing and the strength of the components to be selected by the designer. Components must be dimensioned in accordance with the highest acceleration forces encountered.

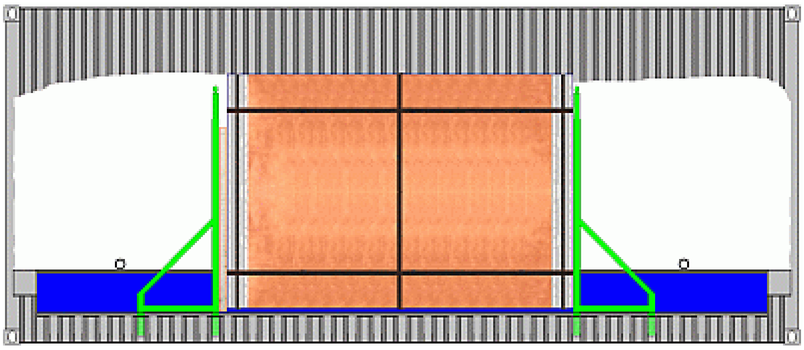
At present, it is not yet usual to find special box containers which have lengthwise cargo troughs which can be covered over and are thus also suitable for carrying general cargo of relatively low stowage factors. Due to their depth, once the troughs are covered over, all that remains is a container with a small volume-to-payload ratio. For some regions of service, constructing such containers may prove entirely worthwhile.



Cross-section of coil box container with one row of stanchions

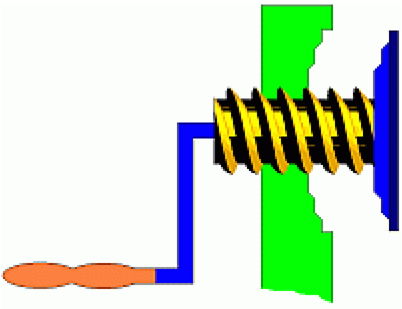


Cross-section of coil box container with two rows of stanchions



Coil box container - side view

Coil box containers with ordinary or special stanchions which can be inserted in one or two rows of stanchion pockets are conceivable. In conjunction with the trough, the stanchions may provide the basis for tight fit securing. Small gaps may be filled with lumber or other similar materials. All stanchions should on principle be secured against being lifted out.



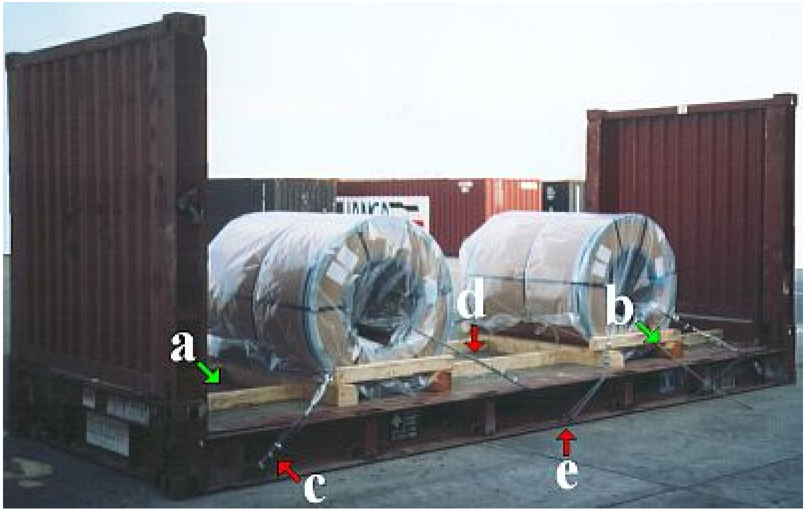
Jack screw fitted into a stanchion to close gaps in the stow

Additional special fitting on stanchions could make it possible to close small gaps with little effort. Cranks, hand wheels or the like are conceivable.

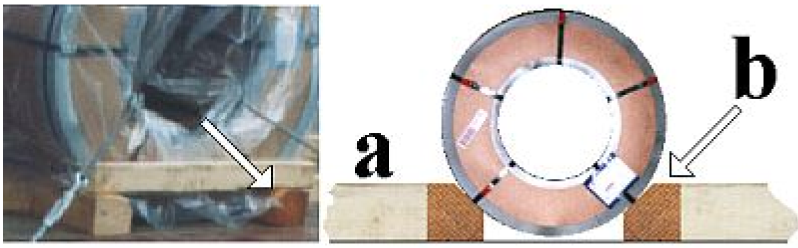
Standard equipment for coil containers or special coil box containers, or indeed for any means of transport, should include a sufficient number of lashing points with a sufficient loading capacity.

5.2.14.3 Coils on flatracks with winding axis lying crosswise

Coils on 20' flatracks



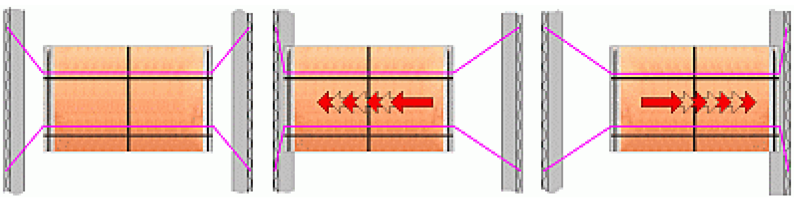
Inadequately secured coils on a 20' flatrack



Wooden beams (a) hold the wedge beams (b) in position.

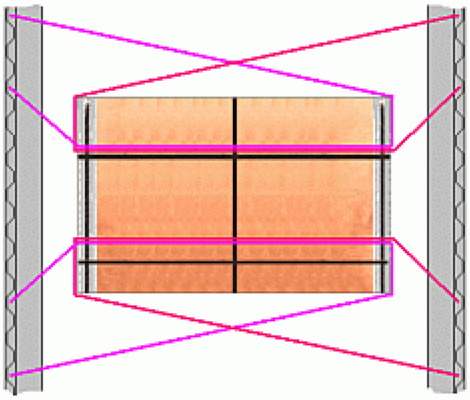
Good features include the use of the chamfered wooden members (b) and the fact that these "wedge" beams are held tightly in place by the lengthwise members (a). The steel sheet rolls rest on the wedge beams in such a way that they are not in contact with the floor of the flatrack in the middle.

However, the lashings have been applied nonuniformly. It can be seen at (c) and (d) that only three, i.e. too few, wire clips have been used. At (e), two lashings have clearly been attached to a single lashing point, which does not have the necessary maximum securing load.



Coils able to move freely in their lashings

However, it is the arrangement of the lashings which is particularly disadvantageous as the coils can move freely in the lashings.

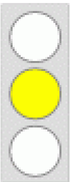


Coil fixed with loop lashings

Using loop lashings can prevent the coils from moving sideways.

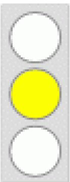
Depending upon the angle, loop lashings can generate horizontal securing forces in the crosswise and lengthwise directions as well as in the vertical direction. The wooden crosspieces nailed onto the wedge beams can be dispensed with as they are relatively ineffective.

In this case, securing was provided by the above-described method using steel strapping.



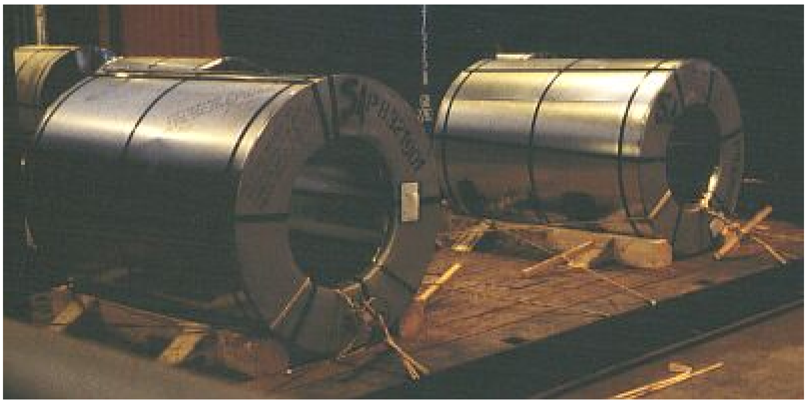
Each coil is secured with two loop lashings per side.

Using wedges to retain the wedge members is unfavorable as they are incapable of holding the latter in position over an extended period. It would have been better to use squared lumber bracing.



Coil securing with two steel strapping loop lashings on each side

The path taken by the loop lashings is more clearly visible in this photograph. It would be better to use edge protectors made from segments of used tires. In this way, it is possible to make up for steel strapping's disadvantageously inadequate elasticity. Moreover, the greatest possible protection is provided for the cold-rolled sheet.

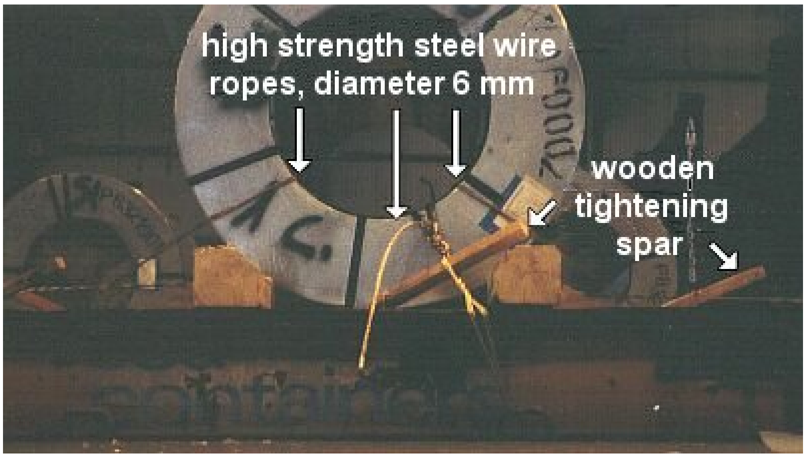


Coil securing with two 6 diameter steel wire rope loop lashings on each side

In this case, the coils are located centrally. Otherwise, the above comment applies here too: it would have been better to fasten the wedge members with wooden bracing. This would not generate additional costs. The costs of the wedges are almost the same as for the squared lumber and labor costs are hardly any higher.

Tensioning steel wire ropes with a "Spanish windlass"

In this case, the steel wire ropes have been knotted and pretensioned with tightening spars. Such fastenings can be applied very quickly. The tightening spars must be made from hardwood and must be properly secured against coming undone. Further details may be found in the general section on cargo securing.

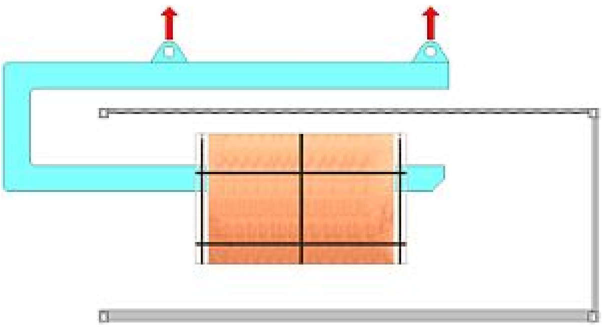


Detail view of wedge members and steel wire rope lashings

5.2.14.4 Coils in box containers with winding axis lying lengthwise

Coils in 20' box containers: winding axis lying lengthwise
General information and options

Introducing coils into open-top containers causes no difficulty. When ordinary box containers are used special equipment or precautions must be used during cargo handling.

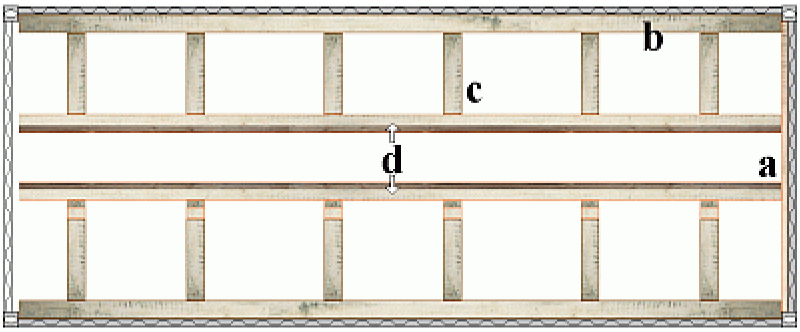


Introducing coils into a box container using a special C hook

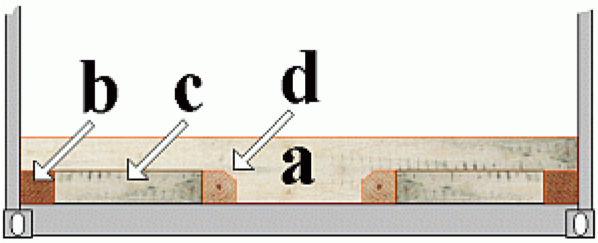
Forklift trucks can only be used for direct handling of low mass coils of up to approx. 2.5 metric tons. Heavier coils must be pushed into the container. This requires special working methods in order to prevent tearing of the strapping and to avoid bruising the coils.

Coils can be pushed in if auxiliary materials are used which have a high coefficient of sliding friction on the coil side and a lower coefficient of sliding friction on the outside. If this is the case, the materials stick to the coil and are "entrained" as the coil is pushed in.

Suitable cradles must be prepared before loading is begun.



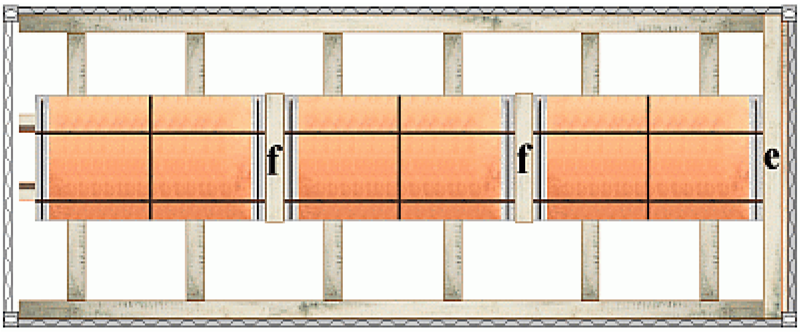
Coil cradle - plan view



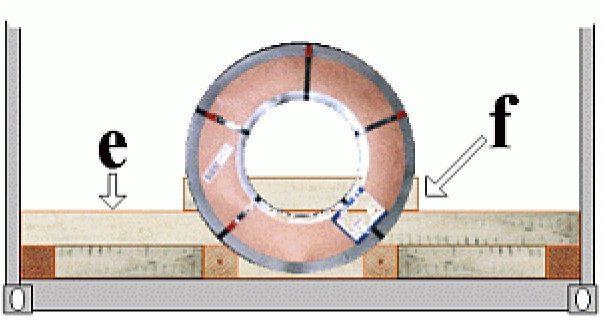
Using boards or planks, the front end wall is braced (a) flush with the corner posts up to twice the height of the lumber size used. Squared lumber (b) is laid down at the sides of the container to distribute pressure. Depending upon the number of coils to be loaded and their mass, crosspieces (c) are laid at right angles to the side beams. Wedge members (d) are then laid lengthwise.

N.B.: Since the coils are subsequently to be lashed, the lashing points must remain accessible. Should these be

located under the lengthwise beams (b), the necessary lashing means can be attached to the lashing points before the wooden members are laid. The lengthwise beams (b) can then be placed on small boards.

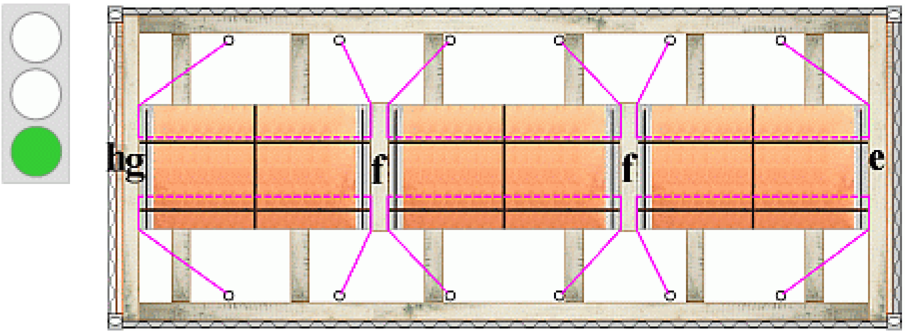


Loading and interim securing of coils - plan view

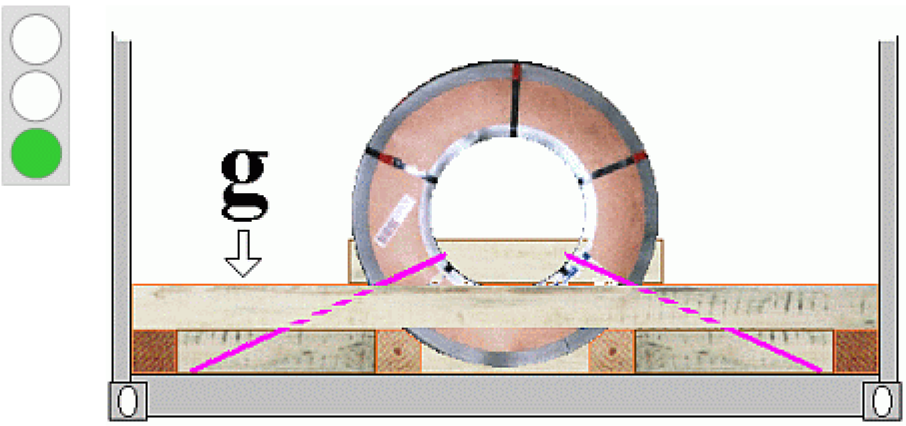


Loading and interim securing of coils - cross-section

Before loading begins, a beam (e) is laid crosswise in front of the boards or planks (a) and the corner posts. This beam (e) lies on the lengthwise members (b) and (d). The first coil is laid against this crosswise beam (e). A shorter beam (f) acting as a spacer relative to the next coil is laid crosswise over the wedge beams (d) and the second coil is loaded against it. The same method is used for the third coil. (f) is at the level of (e) and is only shown higher to make it more visible.



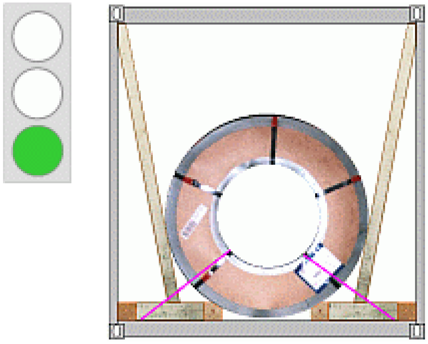
Three coils: blocked and lashed - plan view



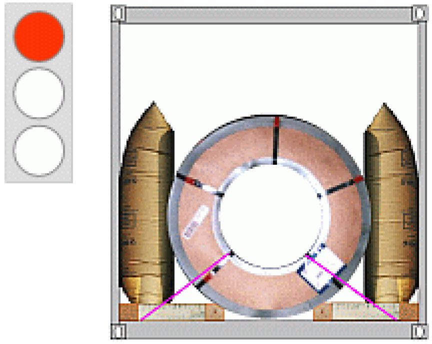
Three coils: blocked and lashed - cross-section

Once the last coil has been placed, the remaining gap towards the container door is filled with squared lumber (g) and boards or planks (h). Each coil is secured with two loop lashings passed through the eye. These lashings secure the coils laterally and prevent them from popping vertically out of the wedge beams under dynamic loads.

Since some of the lashing points are unfavorably located, as is often observed in practice, the resultant angle of the lashings means that they provide, for example, only 60 - 70% of their maximum securing load.



Additional securing by bracing beams



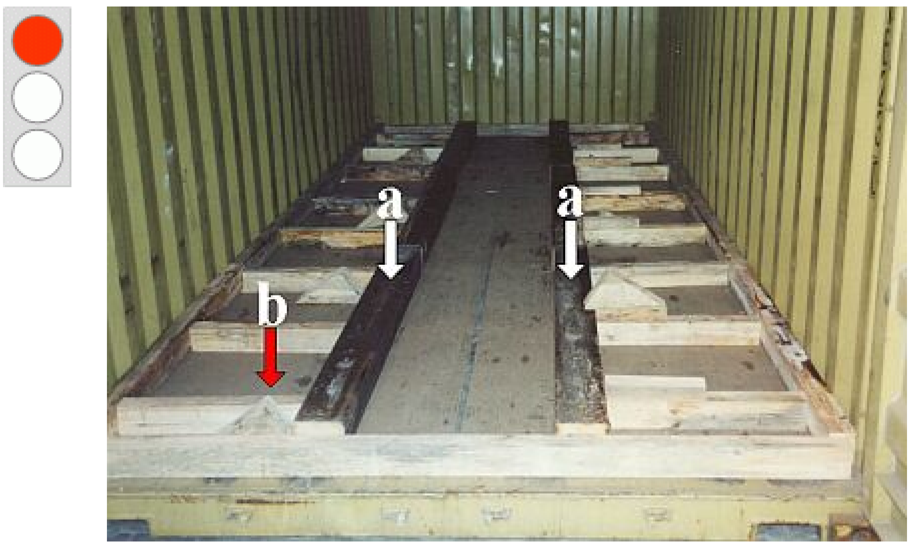
Additional securing with airbags

With larger diameter coils, the flanks of the wedge beams must be at a different angle.

If lashings are inadequate due to unfavorable lashing angles or relatively weak lashing points, additional securing can be provided with shoring beams. As shown in the diagram, the shoring beams are located against the top side rail and, to prevent slippage, between the container corrugations. The greater the web height of the beams, the greater is the flexural strength. In order to save materials, half-size lumber, such as 6 cm x 12 cm or 8 cm x 16, should be preferred.

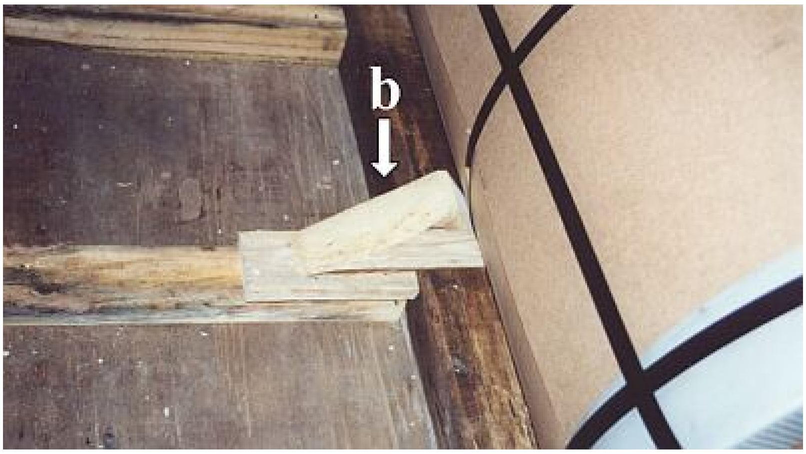
If airbags are to be used, they must be used in sufficient numbers for the forces to apply uniformly over the container walls. However, no significant gain can be expected because, although the container walls can be loaded with 60% of the payload, the majority of the forces are already transferred into the side walls via the wooden crosspieces on the floor. The most important factor, however, when using airbags is that the gaps in the stow must not be excessively large. Experience has shown that gaps of 30 cm should be regarded as the maximum, but smaller gaps are better. The shape of the cargo should moreover be as uniform as possible, as airbags are only able to conform to the shape of the cargo to a limited extent.

Example: Three coils in a 20' box container



Inadequate cradle for accommodating coils

The lengthwise wooden members (a) are not chamfered. If, as should be the case, the coils rest clear of the floor, they will bear down directly on the two longitudinal edges. Wedge beams should have been used. The large number of wedges would indicate that they are intended to provide sideways securing. However, they have not been correctly cut for this purpose.

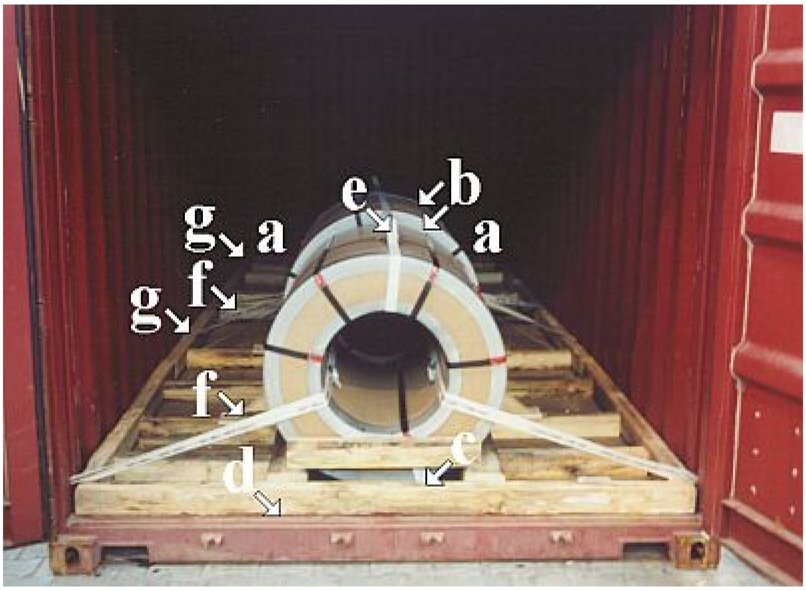


Incorrectly cut wedges - nails will have to be driven into the end grain

The wedges have been cut so that the nails will have to be driven into the end grain. This will result in the wedges splitting, at the latest when exposed to impact in transit . The wedges rely solely on the nail shear forces. High maximum securing loads cannot be expected.

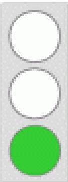
Inadequate lateral securing with wedges

Two wedges were placed by the front coil (the one by the front end wall). Only one wedge was placed by each of the middle and rear coils, the latter closest to the door.



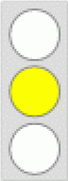
Inadequately applied cargo securing

No wooden members were fitted to provide a tight fit between the front end wall and the first coil (a). There is likewise no squared lumber to provide a tight fit between the coils and the door, (b) and (c). The squared lumber (d) is performing no useful function. The coils are bound together with single-use webbing belts (e). This type of unitization provides no additional securing action. The loop lashings (g) are holding the front and middle coils together, while the loop lashing (f) is holding the middle and rear coils together, latter being closest to the door.



Improved securing with squared lumber members fitted crosswise

The shortcomings in the lengthwise securing can be eliminated by fitting squared lumber in the gaps. The crosspieces at the front end wall and the door have to transfer compressive forces over a large area. The green light only relates to lengthwise securing.



Loop lashings with single-use webbing belts

It is essential to take note of the labels on the belts or other information from the manufacturer. The maximum securing load should be assumed to amount to at most 70% of the breaking load, or better still only 50%. Note the uniformity. The belts shown in the picture have a higher maximum securing load than the lashing points. Moreover, the lashing points are round and thus not suitable for fastening belts. Shackles should be used to join the belt to the lashing point, with the webbing belts being passed over the shackle pin.

5.2.14.5 Coils on skids, horizontal winding axis

Coils with horizontal winding axis on skids

Coil set down on a skid and fastened with steel strapping

There is no need to address the securing of these cargoes separately. Where possible, packing should be carried out so that the lower layer of the wooden sled members are at right angles to the container bottom cross members. If dimensions do not permit this, the cargo must be packed either crosswise or lengthwise. If the bottom wooden sled members run parallel to the container bottom cross members, it must be verified that the container line load is not exceeded. If this is the case, additional wooden members must be provided to distribute the pressure. Any remaining gaps should be filled with lumber at the height of the load-bearing parts. Loop lashings should also be passed though the eye to provide further securing. In no event should tie-down lashings, as shown in the picture, be used. If bracing and/or loop lashings are not enough, or if they are difficult or impossible to apply, the option still remains of applying shoring against the load-bearing wedge beams or the other wooden sled members encompassed by the strapping. In individual cases, subject to compliance with the basic rules for using airbags, it may be possible to use airbags alone or in addition to other securing means. If the steel strapping is too weak or could slacken because, as shown in the picture, it has been passed over the edge of the lumber without an edge protector, it must be securely fastened to the skids by additional means.

Where possible, friction-enhancing materials should be laid under the skids. If the cargo has to be slid into its stowage space, such materials can only be laid, if at all, once the cargo is in position. This requirement also applies to the following examples.

5.2.14.6 Coils on skids, vertical winding axis

Coils and slit strip coils with a vertical winding axis

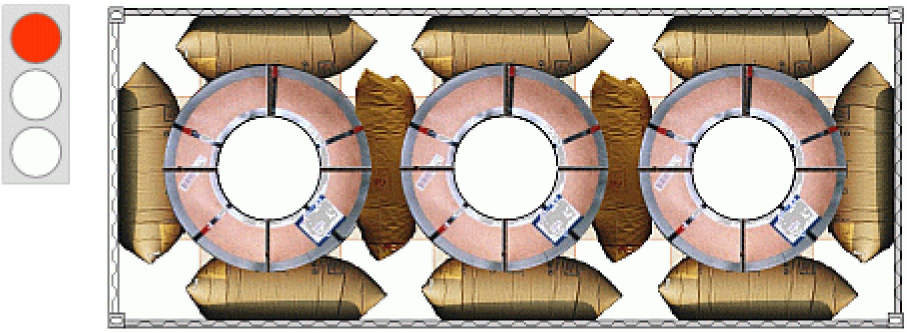
Slit strip coils - fastened onto wooden sleds with steel strapping

Before loading, attachment to the skids should be checked. If the method of application or condition of the straps gives the impression that they could slacken or be unable of withstanding anticipated acceleration forces, additional attachment to the skids should be ensured.

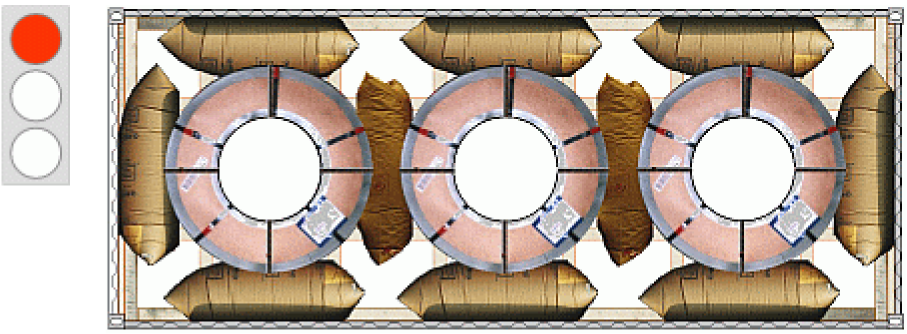
Depending on their dimensions, coils should where possible be packed without gaps. Any remaining gaps should be filled with lumber members. Lashings may be passed through the eye, but only if the coil is not completely shrink-wrapped. If lashings cannot be passed through the eye, shoring is very effective in preventing slit strip coils from moving.

In some cases, it is entirely possible to secure even slit strip coils with airbags.

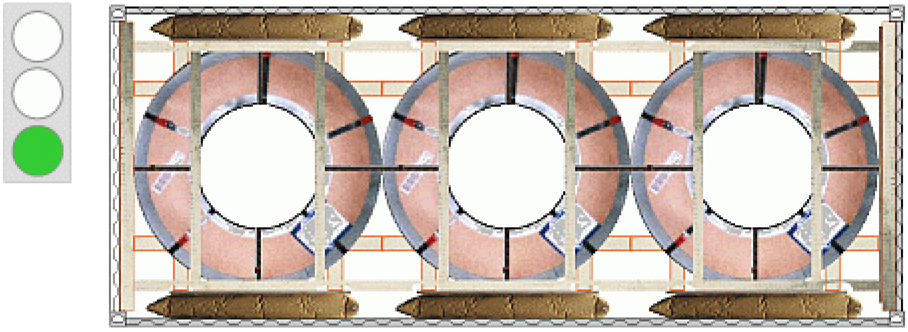
Some suggestions and comments on securing are given below. Some may be applied as alternatives, some in combinations while still others should not be used.



Not like this, please: securing of coils/slit strip coils with airbags - plan view



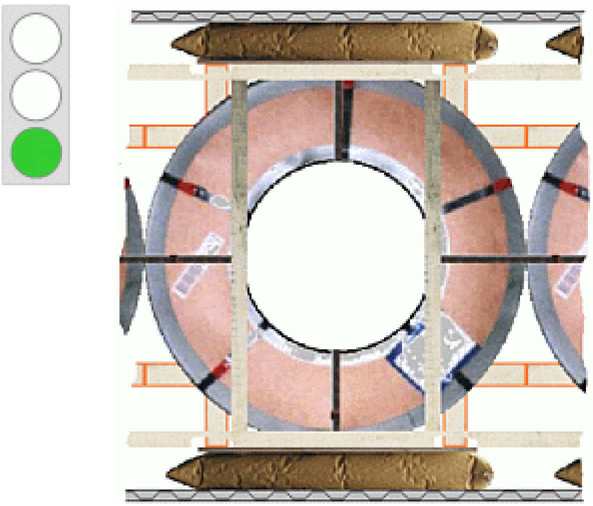
Inadmissible use of airbags - plan view



Possible: sideways securing with airbags - plan view

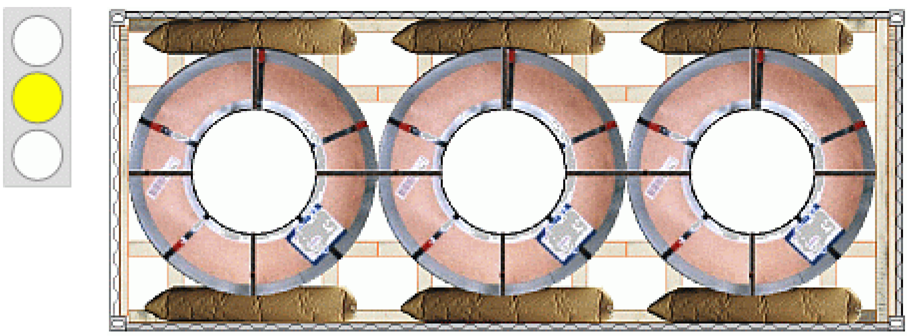
Securing was provided at the front end with a beam lattice and a walking board. A walking board was stood at the side of each coil, the board being braced at the bottom against the sled and at the top against a wooden frame. Each walking board also rests against the outer edge of the coil. The airbags have only a small gap to fill. Bracing with beams is provided in the door area. In the drawing, the upper frames are shown slightly offset to give a better view of the overall securing arrangement. In practice, they should be positioned perpendicularly above the wooden sled members.

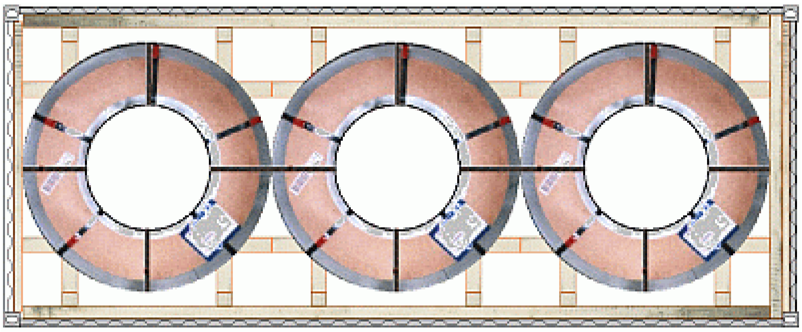
This detail drawing clarifies the situation:



Possible: sideways securing with airbags - plan view

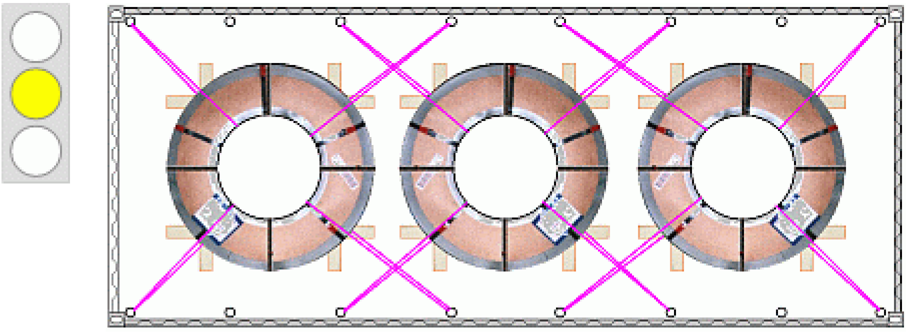
It should be noted, however, that these and the following examples with three coils are not entirely realistic as the coil diameters are very large and they can accordingly only be coils or slit strip coils with a short winding axis, as the masses would otherwise exceed the container payload.





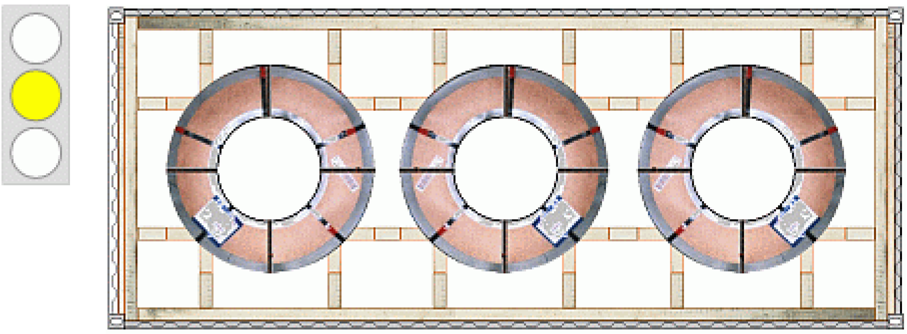
Feasible: securing of tightly fastened coils with bracing at floor level, airbags to provide support - plan view

In this variant, the use of airbags is quite likely. The coils are wide, but flat and not at risk of tipping. The coil is blocked at floor level and towards the ends. Strapping to the skids is sufficiently strong. The airbags are merely intended to relieve the load on the coil strapping on the sleds.

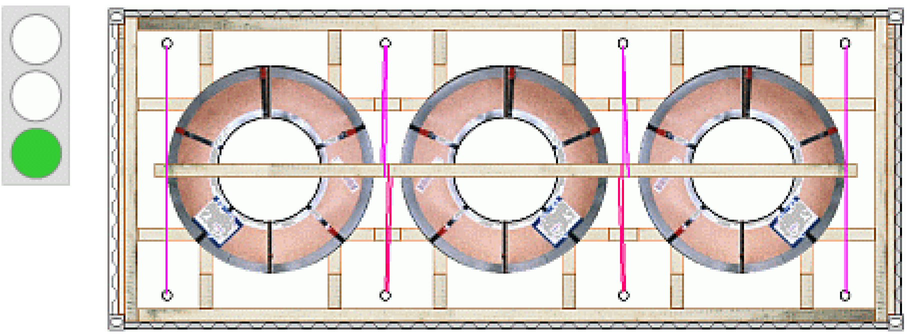


Securing of coils/slit strip coils with loop lashings passed through the eye - plan view

Depending on the mass of the cargo and the maximum securing loads of the lashings, this method may be adequate by itself. With high cargo masses or low maximum securing loads of the lashings, additional measures should be taken.

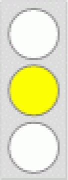


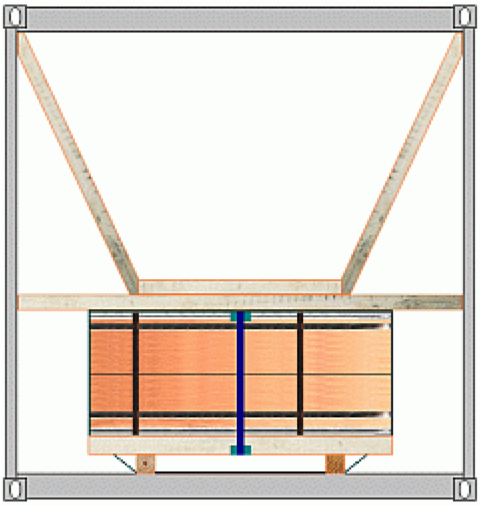
Securing coils/slit strip coils with wooden bracing - plan view



Securing with squared lumber and hold-down members

Skids braced only at floor level could escape the bracing if tipped up. In order to counter this risk, they must additionally be held down. This may be achieved by using squared lumber together with "tie-down lashings" and/or loop lashings. When applied in this manner, "tie-down lashings" act as direct lashings against upward motion. Tie-down lashings cannot be used alone because the lumber used to hold down the cargo could otherwise shift.

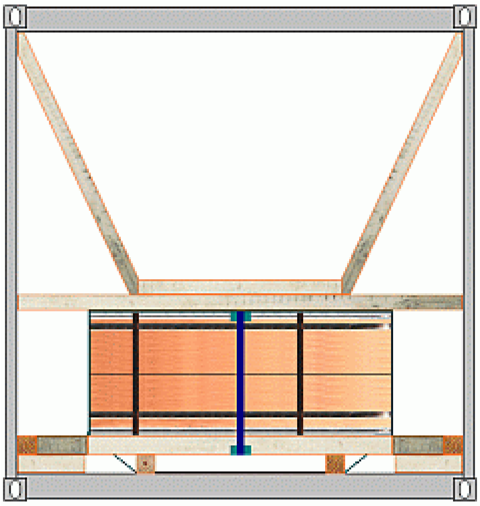




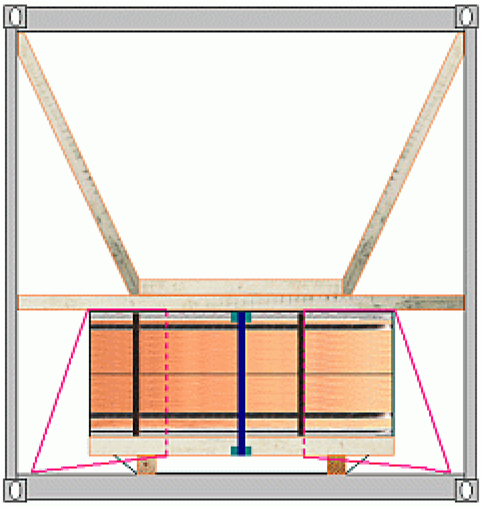
Securing of coils/ slit strip coils with shoring - cross-section

Shoring in conjunction with friction-enhancing materials, may be sufficient if the shoring members are driven strongly apart and so generate large pressure forces. This cannot be done with large masses because admissible line loads would be exceeded.

Securing with wooden bracing at floor level and shoring - cross-section



If the cargo is secured at floor level by wooden bracing, the shoring members need only be set in place, but not driven strongly apart. It is vital in all cases for the strapping to be able to hold the coils onto the sleds over an extended period.

Securing with loop lashings through the eye and shoring - plan view

Passing loop lashings through the eye has the advantage that the load on the strapping is relieved.

5.2.14.7 Wire rod coils with winding axis lying crosswise

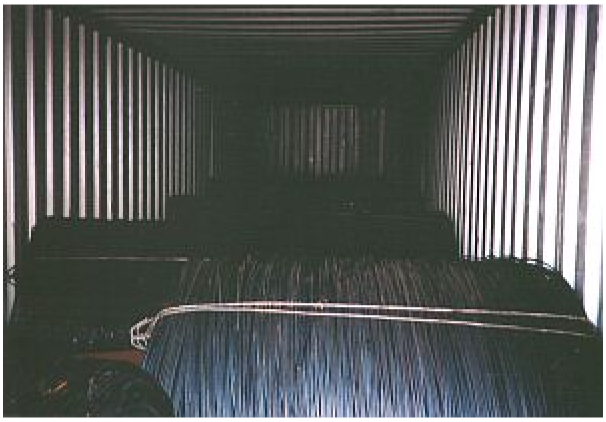
Depending on the nature of the goods and any intended subsequent processing, coils of wire rod are sensitive to corrosion and to mechanical damage, for example, kinks forming in the wire. The length of the winding axis is a critical factor in determining the way they are stowed.


Shortcomings in packaging a wire rod coil

The base of the wire coil protrudes and thus complicates loading and securing. Including lumber components in the plastic wrapping increases the risk of corrosion as condensation can form under the covering.


Inadequate stowage and securing of wire rod coils

The wire rod coils have simply been set down alternately against the container side walls. Sheets of cardboard have been inserted at the contact points between the coils.

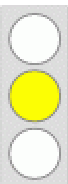


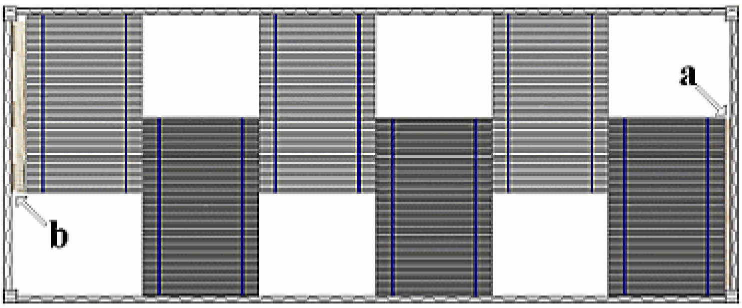
View into a container with wire rod coils

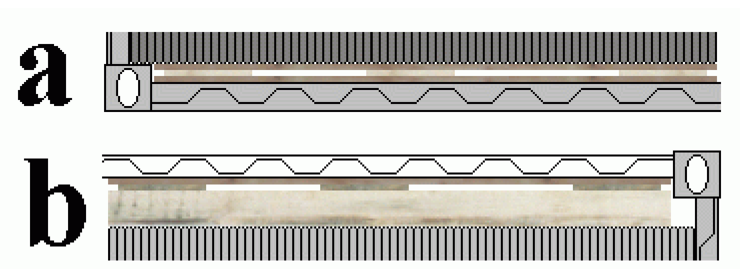
The wire rod coils are in direct contact with the container side walls. This may result in chafing of the container side walls. The wire rod could then suffer corrosion if water vapor from the cardboard, the container floor and similar sources were to condense in relatively large quantities on the container roof and walls and be able to wet the wire rod coils.

Gaps in a container packed with wire rod coils

The gaps in the container cargo would only present no risk if the wire coils were 100% solidly intermeshed.

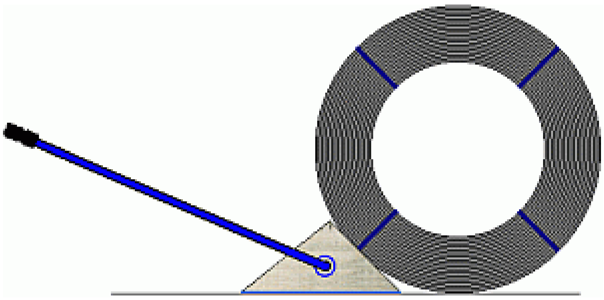






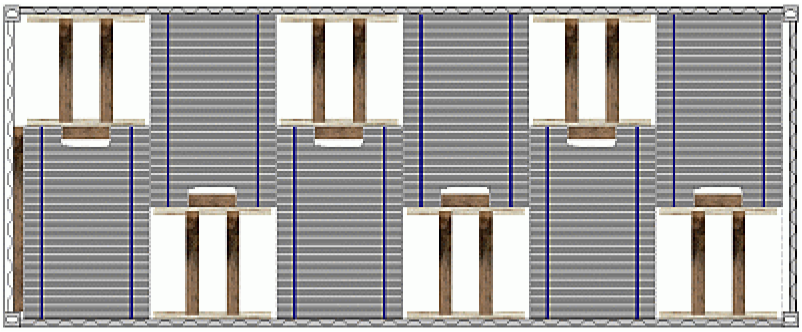
Compact, intermeshed stowage - lengthwise gaps filled

This may be an acceptable loading method not entailing major securing effort if dimensions permit extremely compact packing and the wire coils are able to intermesh effectively without resulting in damage to the goods. In the example shown in the diagram, the gap between the front end wall and the inner edge of the corner post is filled with a wooden lattice (a) of horizontal and vertical boards, onto which a board is nailed horizontally at winding axis height. The coils are arranged on alternate sides and tightly pressed towards the front end wall. Once the left door leaf had been closed, the remaining gap was filled with a lattice (b) of boards and a squared lumber member at winding axis height.



Wedge with handle for restraining wire coils

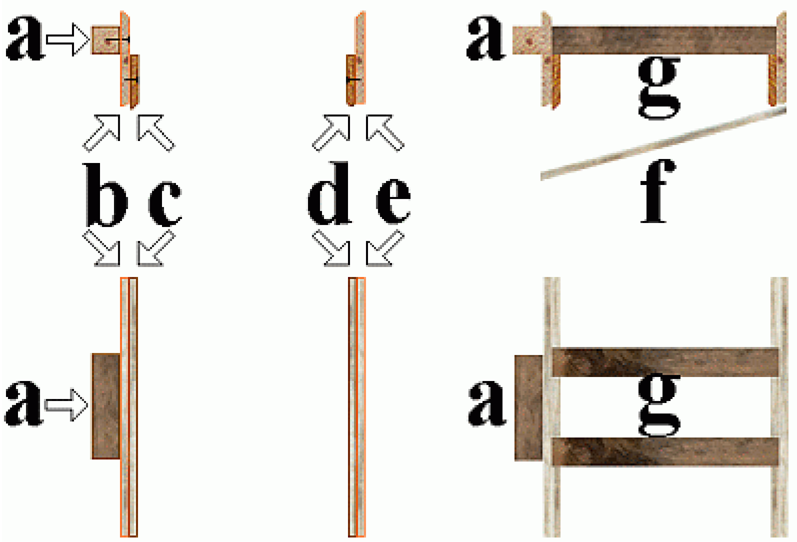
To stop the preceding coil from "slackening" before the next one is loaded, the first one can be held in its initially loaded position using a wedge with a handle.



Wire rod coils packed with winding axis crosswise - secured with wooden bracing

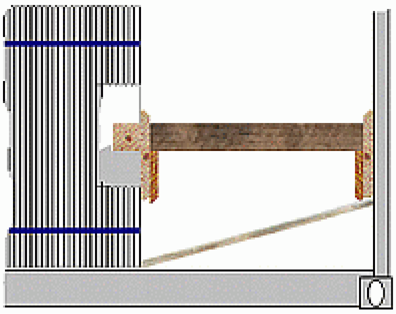
Provided that there is no risk of corrosion or kiln dry lumber is used, the wire rod coils could be secured as shown here in the diagram.

The coils could each be secured in the lengthwise direction with wedges. In this example, however, in order to prevent wetting damage, it is important to place as little kiln dry lumber in the container as possible.

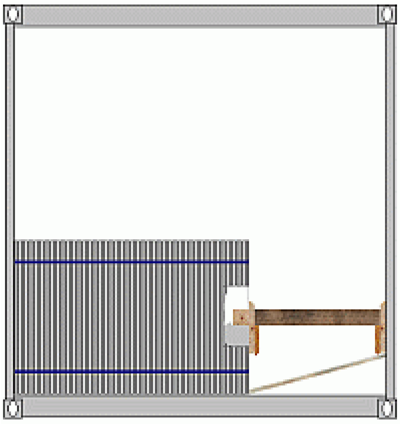


Preparation of wooden bracing

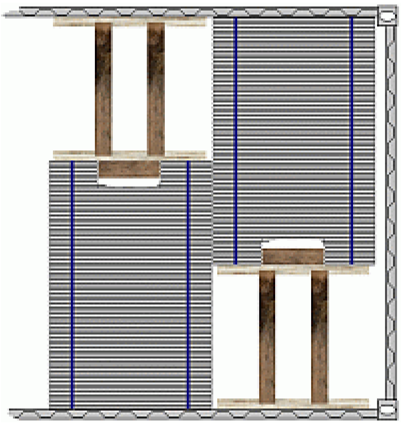
Short squared lumber members (a) and two boards (b) and (c) are nailed together. The short squared lumber members should be of dimensions such that they exactly fit into the wire rod coil eye. The boards (b) and (c) overlap one another in steps. Two further boards (d) and (e) are joined together in the same manner. Between these pairs of boards are fitted two squared lumber members (g) which are dimensioned such that, together with the thickness of the four boards, they fill the gap in the load. These bracing structures are located with the squared lumber members (a) in the eyes of the wire coils in such a manner that the boards (d) and (e) rest against the container walls. They are prevented from slipping down by inserting oblique boards (f).



Bracing fitted into the eye of a wire coil



Section through the container



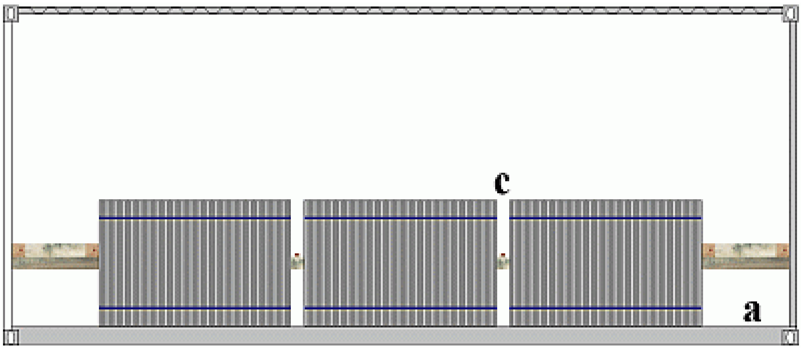
Plan view of two wire coils

Assuming a coefficient of sliding friction of μ = 0.2 and transport acceleration values of 0.8 g in the sideways direction, the container's full payload can be utilized as the container side walls are capable of withstanding 0.6 times the payload uniformly applied. It is, however, recommended that strips of friction-enhancing material be laid under the wire rod coils.

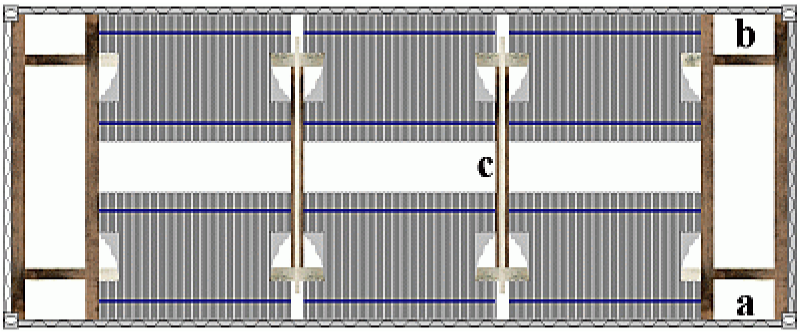
Since the wire coils are able to roll in the lengthwise direction of the container, no coefficients of sliding friction need be assumed for the lengthwise direction. Compact packing in the lengthwise direction is only adequate if (due to the loading capacity of the container end walls of 0.4 times the payload) the acceleration values anticipated during shipping do not exceed 0.4 g. If higher levels of acceleration are anticipated, the wire coils should be secured in the lengthwise direction with additional wedges or wedge beams which are capable of absorbing a proportion of the forces.

5.2.14.8 Wire rod coils with winding axis lying lengthwise

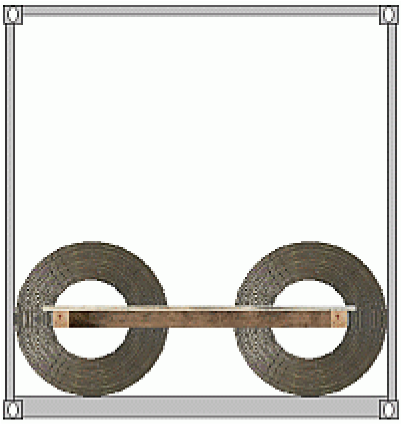
The following variant shows securing options using wooden members which are passed through the eyes of two rolls or coils and braced together. In this case, the coils rest with their sides against the container walls.



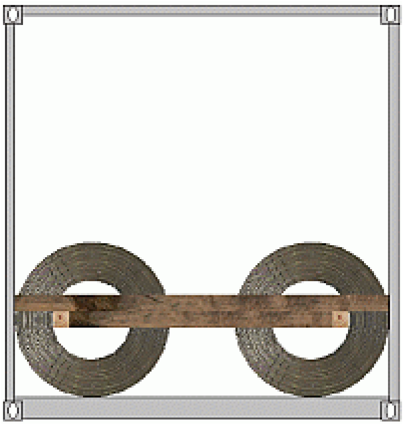
Wooden members passing through rows of coil eyes - side view



Overall arrangement of wooden members - plan view

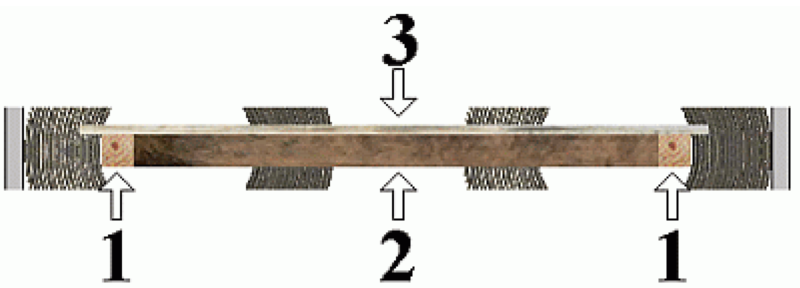


Cross-section at c



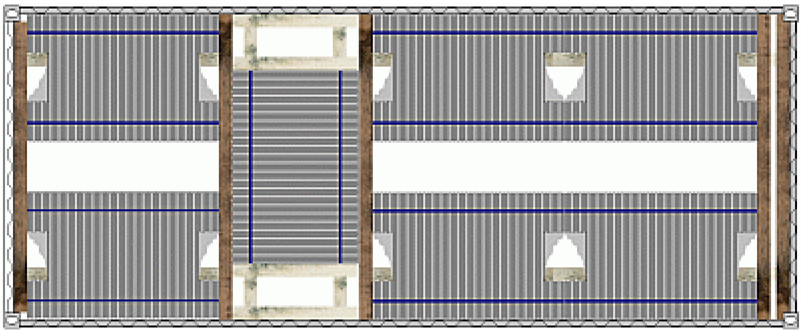
Cross-section through a and b

This method is technically relatively simple to implement.



Detail of sideways acting bracing

The squared lumber members (1) passed lengthwise through the coil eyes are pressed apart by the squared lumber member (2) fitted crosswise between them. This wooden member is held in place by the board (3) nailed onto it. This securing method on the one hand results in the formation of a compact block and on the other prevents the coils from rolling, so preventing overloading of the container walls. Without this "braking" action, the container side walls would be subjected to excessive loads.

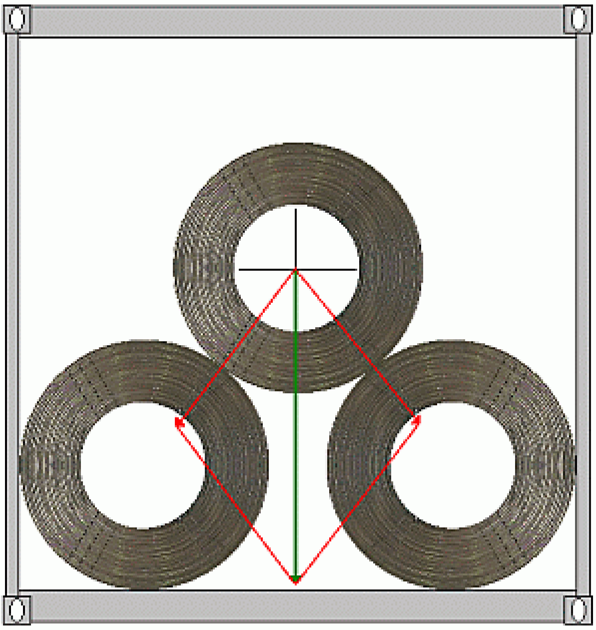


Packing and securing variant with seven wire rod coils

Packing and securing means should be decided before loading by means of appropriate stowage planning.

Heavier wire coils in box containers

This diagram indicates what additional measures may be required.



Aluminum wire coils packed in the cantline

The lower layer is subjected to additional forces due to the "angle of rest" of the upper layer. Since the coils can roll apart, the container walls will be exposed to the entirety of the forces which can arise from acceleration of shipment. If this type of packing is to be used, some way must be found to relieve the load on the container walls. This could be achieved by loop lashings passed through the eyes of the bottom pair of coils.

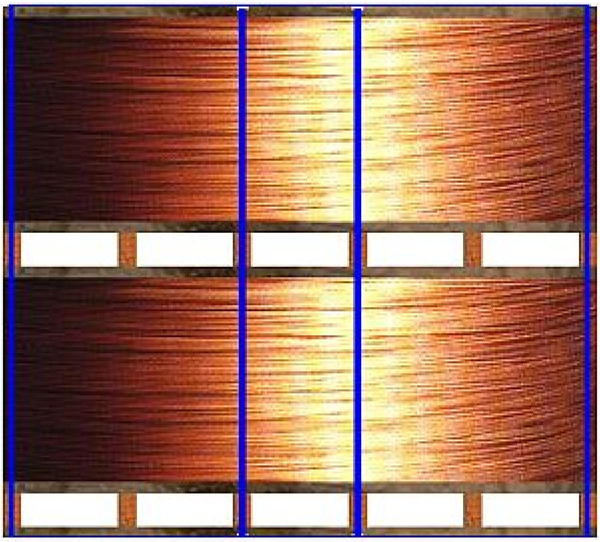
5.2.14.9 Electrolytic copper coils on pallets

Electrolytic copper coils

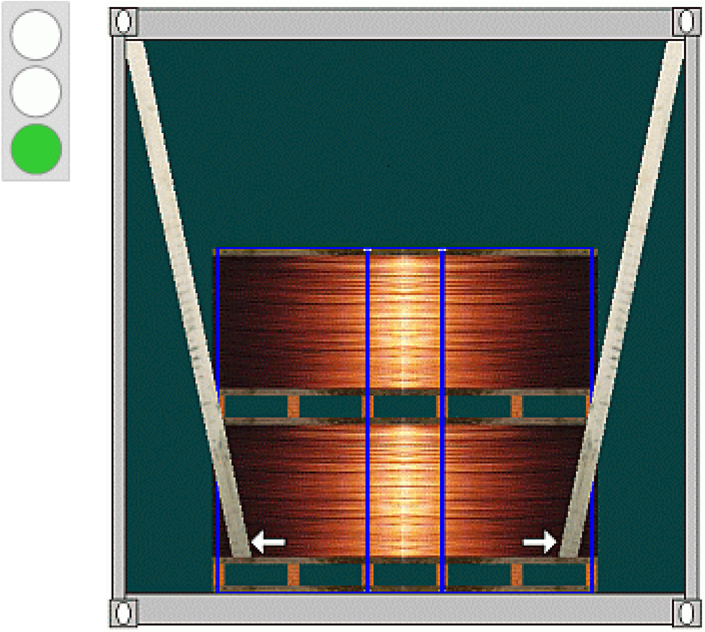
Copper wire is denser than steel. A pallet with a coil of 8 mm thick wire with base dimensions of 1.60 m x 1.60 m and a height of 0.70 m weighs approx. 3.5 metric tons. The coils themselves are 1.60 m in diameter and 0.55 m tall.

Pallet with copper coil

The pallets can be shrink wrapped and strapped for transport purposes. This makes it impossible to secure the coils by loop lashings through the eye. One option for packing in containers is to group together pairs of pallets into an intrinsically very strong transport unit.



Cargo unit comprising two copper wire coils

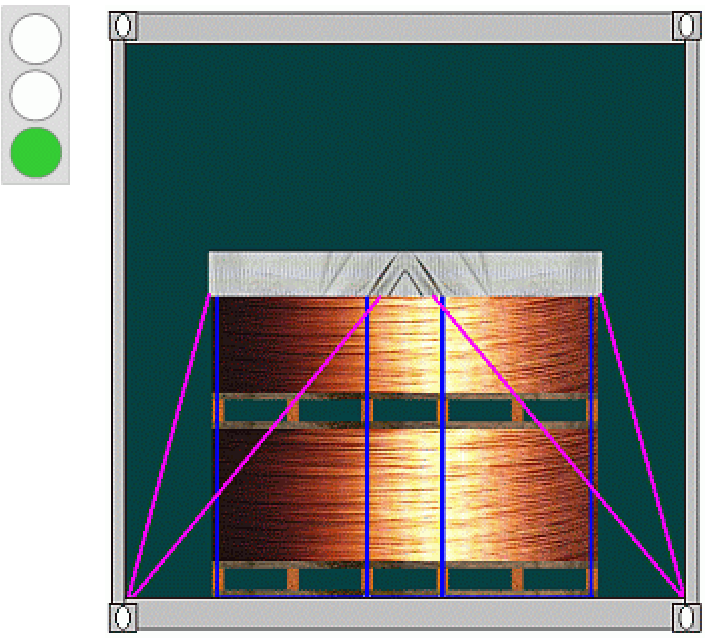


Cargo units secured by shoring

Warning: Due to the particular shape of the pallets used, particular care must be taken not to damage the copper when driving the wooden members apart. Shoring can only be nailed down into the pallet corner members, while wooden cross pieces cannot be used to fix shoring in place when pallets are flush loaded.

The feasibility of other variants using additional wooden members or similar methods must be assessed on the spot.

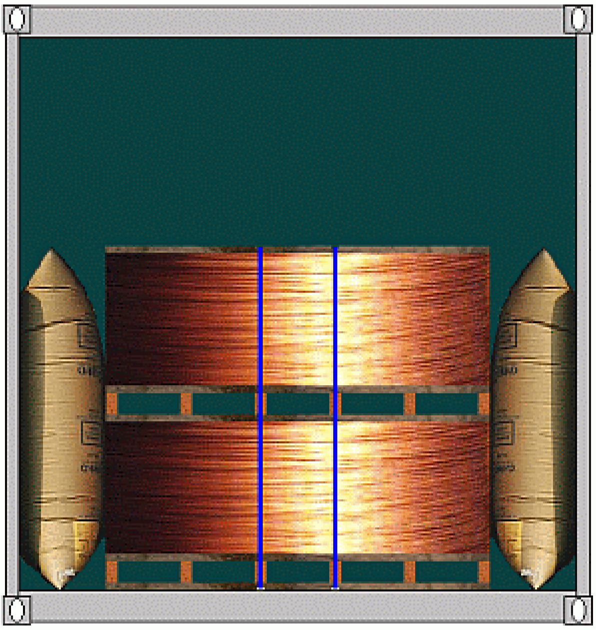
With open-top containers, the cargo units can easily be set down on friction-enhancing material, which ensures that only very slight securing forces need be applied. However, if the pallets are pushed into place with forklift trucks, this is not possible. The pallets may, however, be securely shored in place with four dry squared wooden members per pallet. The wooden members required for this purpose rest on the pallet corners which are not occupied with cargo and against the container top side rail between the corrugations. They are driven apart at the bottom and nailed down to stop them slipping back. Alternatively, the wooden members may also be held in place relative to the container sides with strapping or rope.



Securing with a special cargo securing tarpaulin

One option for securing cargo units without using additional wooden members is to use special cargo securing tarpaulins. In this case too it is advisable, where possible, to set the cargo units down on friction-enhancing material.

It is not generally possible to secure such cargoes with loop lashings through the eye as the cargo is generally shrink wrapped on the pallets.



Securing with airbags

Securing with airbags is theoretically feasible, but given the size of the gaps to be filled rather inexpedient. Airbags must not be used in the door area for safety reasons. In order to ensure uniform load distribution, one cargo unit would have to be placed by the front end wall, one in the middle and one flush with the doors of the rear end wall. With pallet dimensions of 1.60 m x 1.60 m, a gap of approx. 0.60 m will be left between the first and second and between the second and third cargo units. This is larger than it is reasonable to fill with airbags.

5.2.14.10 Round bars and profiles

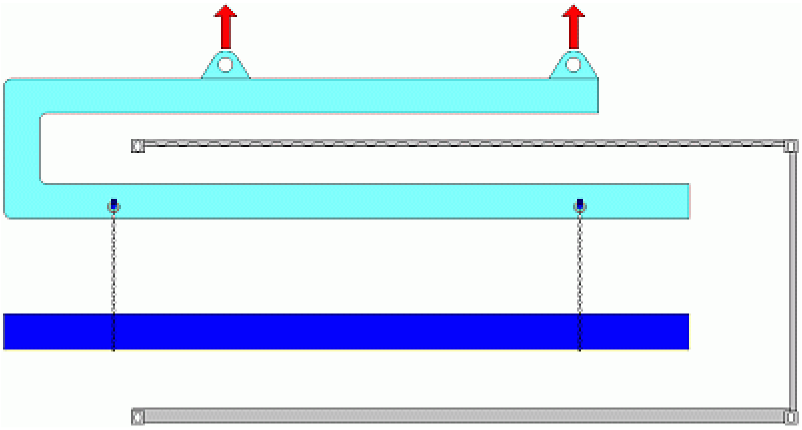
Examples - round bars in 20' box containers - general

Long round bars, profiles and similar cargoes, especially when carried in large weights, are ideally suited to transport on flatracks, providing that there is no risk of depreciation due to corrosion.

It is generally straightforward to load, pack and secure such cargoes on flatracks, especially those equipped with stanchions. Loop lashings to the side and wooden bracing in the lengthwise direction are usually a quick and economic solution for virtually any long loads. Open-top containers provide better protection from weather and can also be packed straightforwardly, but have fewer cargo securing options than do flatracks.

It is only with difficulty and using special aids and working methods that the above-stated cargoes can be packed in standard box containers, with packing often being easier than the subsequent unpacking.

Packing can proceed relatively straightforwardly if special load suspension devices, such as specially designed C hooks, are available.



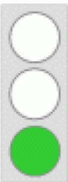
Inserting a round bar into a box container using a C hook

For various reasons, packing with conventional ground conveyors, such as forklift trucks with a low load-carrying capacity, is not very economic:

- Repeated forklift truck maneuvers are needed in order to position the cargo lengthwise in the container door area.

- The cargoes must be pushed into the container with the forklift truck, so dramatically increasing the risk of floor damage.

Cargo handling can be carried out more efficiently if it is possible to use forklift trucks with a very high load-carrying capacity (relative to the weight of the cargo), as, in the method shown, the load center distance is a very long way from the fork face.

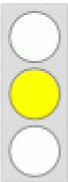


Using a high capacity forklift truck

The load-carrying capacity of the forklift trucks used must vastly exceed requirements, as the forks and lifting apparatus may be damaged by unevenly applied forces.

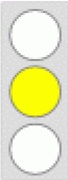
Wrong - the container floor can be scratched when pushing cargoes in and equipment may be damaged too.

The chain used here with the forklift truck is too long. The forward end of the round bar is touching the floor. No further adjustment of the mast is possible. Lifting the forks is of only limited assistance, as not all forklift trucks have such a large free lift or such a low overall height that the cargo can be set down directly. In most cases, such cargoes will end up being pushed into place.



Inserting a round bar with a forklift truck

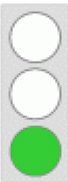
With two chains attached, the round bar can be steered better. Placing wedges once the roll has been set down to secure it provisionally and prevent it from rolling away is a useful accident prevention measure. They are not entirely suitable for cargo securing.



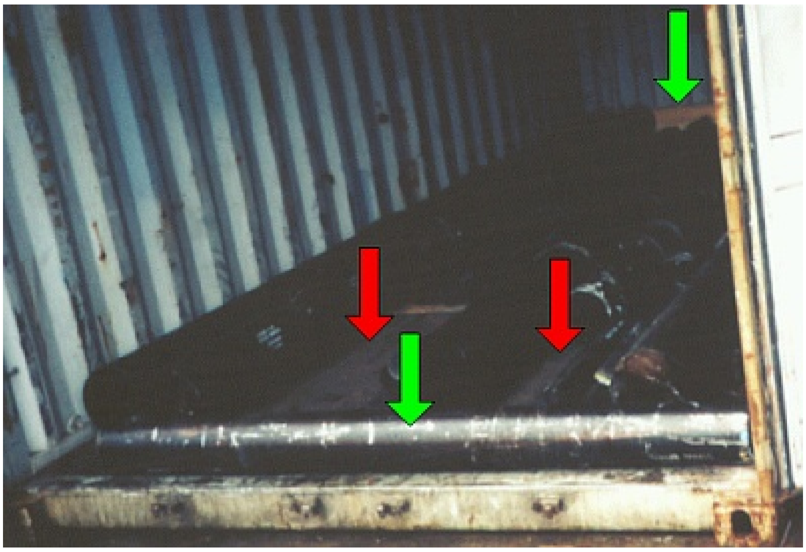
Risk of dangerous sagging

It must be checked in every case whether the cargo can tolerate being handled as illustrated or whether it could be damaged in this way.

Warning: A forklift truck should only be used in this way if there is no risk of breaking accident prevention regulations or damaging the cargo.



Inserting profiles with a forklift truck



Stowing without gaps or filling any gaps which occur is a fundamental requirement.
Advantageous: Buffer stow in the door area

It is certainly correct and important to protect the front end wall of the container with sufficiently strong and tall squared lumber members before round bars are pushed in or set down. If, as in the door area, a suitably sized round bar is available, it should be used as a buffer, but obviously only, as in the present case, with a single layer stow. Correct sizing of the wooden members or using cargo as a buffer precludes penetration through the front end wall and the doors.

Incorrect use of material: the wedges:

It makes no sense to use costly wedges to "plug" gaps or as "wooden fixings". On the plus side, it should be noted that the wedges have been correctly cut for the use shown. Nailing into the face grain is possible. The only problem is, just what can two, three or four nails driven into a 1 inch container floor do to withstand such masses? Filling the gaps with squared lumber offcuts or beam format lumber (e.g. 6 cm x 8 cm) is entirely sufficient. Even roofing laths (e.g. 3 cm x 5 cm or 4 cm x 6 cm) would still be sufficient. Such wooden members need only be fitted into place and attached to the floor.

Incorrect use of wooden wedges

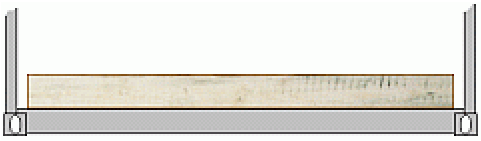
Incorrect use of the wedges is even more obvious in this case and there are incorrectly cut wedges there too.

Inadequate result, despite the correctly cut wedges

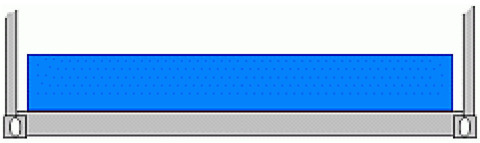
Although the wedges have been correctly cut, adequate securing force cannot be achieved with them. The nails driven into an approx. 1 inch container floor cannot provide sufficient cohesive resistance. However, the wedges are placed incorrectly by the round bars to provide a sideways securing action.

The following method may be used for a single layer stow:

Wooden buffer member at the container front end wall



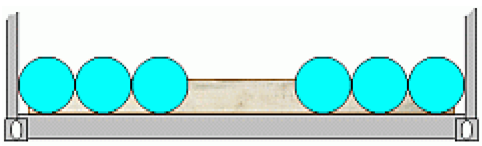
First of all a sufficiently thick and tall squared lumber member is fitted between the container front corner posts. If wooden members of an appropriate thickness and height are not available, the buffer is produced from several pieces of squared lumber. The wooden members should be at least half as tall as the round bars to be stowed.



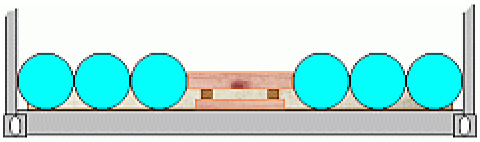
Round bar from the cargo as buffer

Alternatively, if the batch to be stowed also includes shorter round bars, which can fit crosswise into the container, one of them can be used as a buffer. In this way, there is no need to use lumber to create the buffer.

Round bars stowed against the front end wall buffer

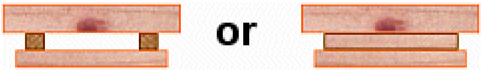


The round bars are stowed against the front end wall buffer and tightly against the container side. For safety reasons, small wooden wedges should be laid beside each bar as it is put in place so that the bars remain in position.



Gap between round bars filled with bracing

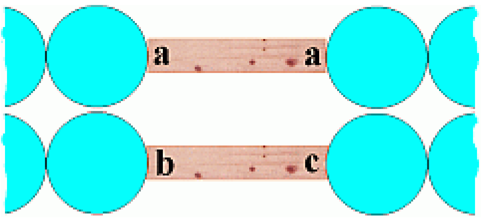
Wooden bracing to fill the gaps between the bars



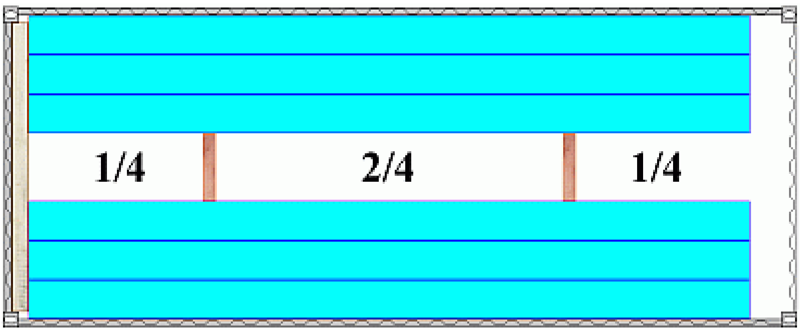
The precise distance between the bars and the height of the center point are determined. Two of the wooden braces shown are built outside the container from offcuts and a wooden member cut a few millimeters longer than to fit and are then fitted between the bars.

Only the squared lumber member at the central bar axis height must be correctly cut to size. Since the wooden members are a few millimeters too long, they have to be driven in crosswise and so provide a somewhat larger contact area. The other wooden members can be waste and offcuts.

Enlargement of contact area



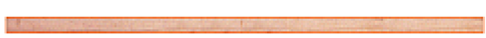
The strip-like bearing surface at (a) can be calculated to apply 100 daN per square centimeter of contact area. Hollowing out the ends with a chain saw (b) or cutting a slight bird's mouth (c) can increase the bearing area and also improve the grip of the wooden members.



Placement of cross braces - plan view

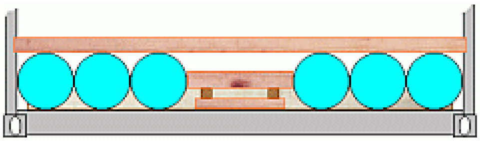
The bracing members should be placed in each case a quarter of the bar length from the ends of the bars.

If the calculated values for two cross braces are insufficient for the mass of the cargo, appropriately thicker wooden members or a larger number of cross braces should be used.

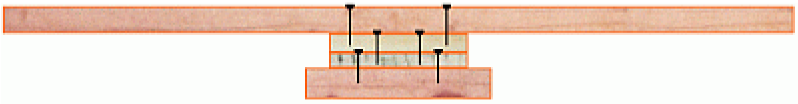


Base beam for shoring

Close to the bracing, the internal width of the container is measured within the corrugations. A 6 cm x 8 cm beam or an 8 cm x 8 cm squared lumber member is cut to exactly this length and then fitted into the container.

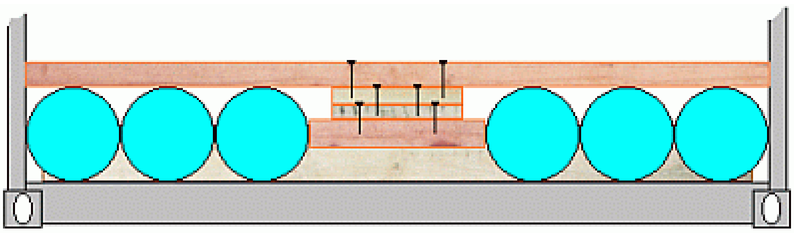
Bracing and base member for shoring 

As an alternative to the four preceding operations, the following method may be used:



Combined wooden member for suspension from above

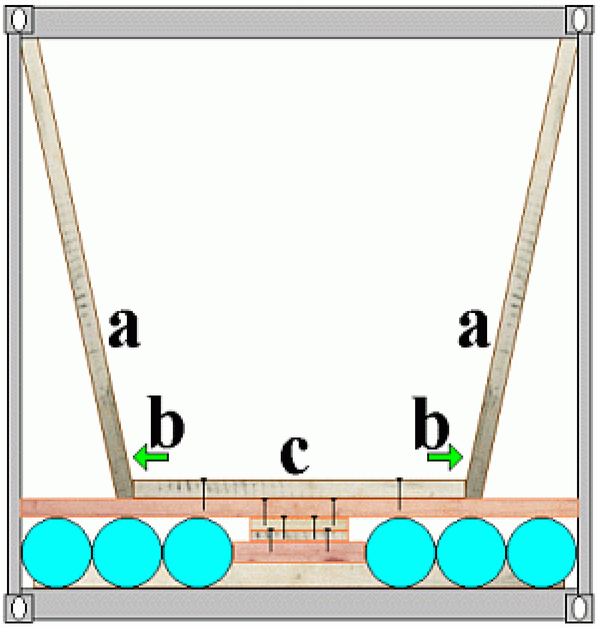
A squared lumber member is cut exactly to the size of the gap. As described previously, a beam is cut to the internal width of the container between the corrugations and, using a few pieces of waste lumber, the bracing member is nailed centrally under the base member for the shoring so that it exactly fills the gap between the round bars:



"Combined member" in place

The details stated above regarding the size of the contact areas and calculating the achievable strengths apply here too.

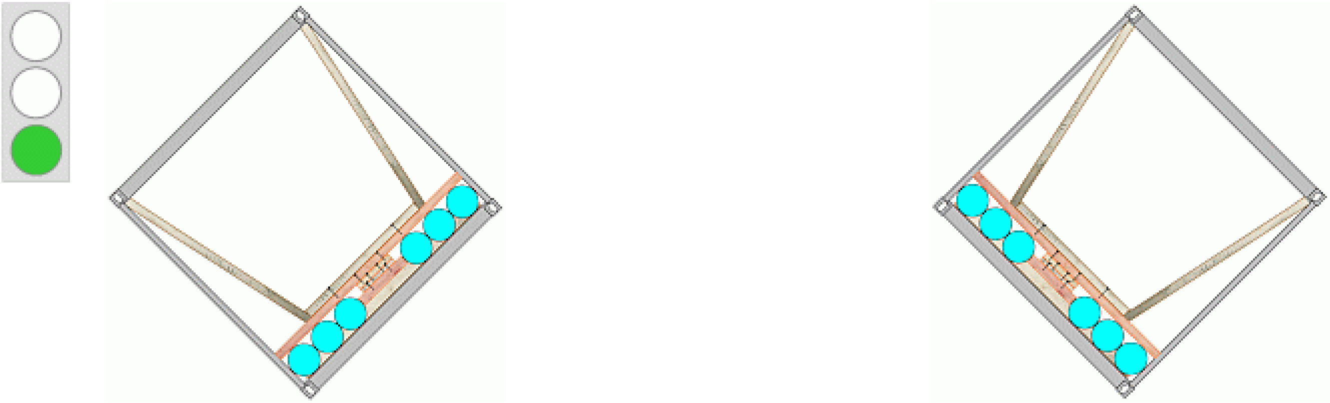
Two shoring members (a) are cut to size to rest on the base member and set in place in accordance with the following diagram so that they are braced against the top side rails. The wooden members are driven apart with a few hammer blows (b) and a securing member (c) is nailed in place to prevent the shoring members from moving back inwards.



Shoring for securing round bars

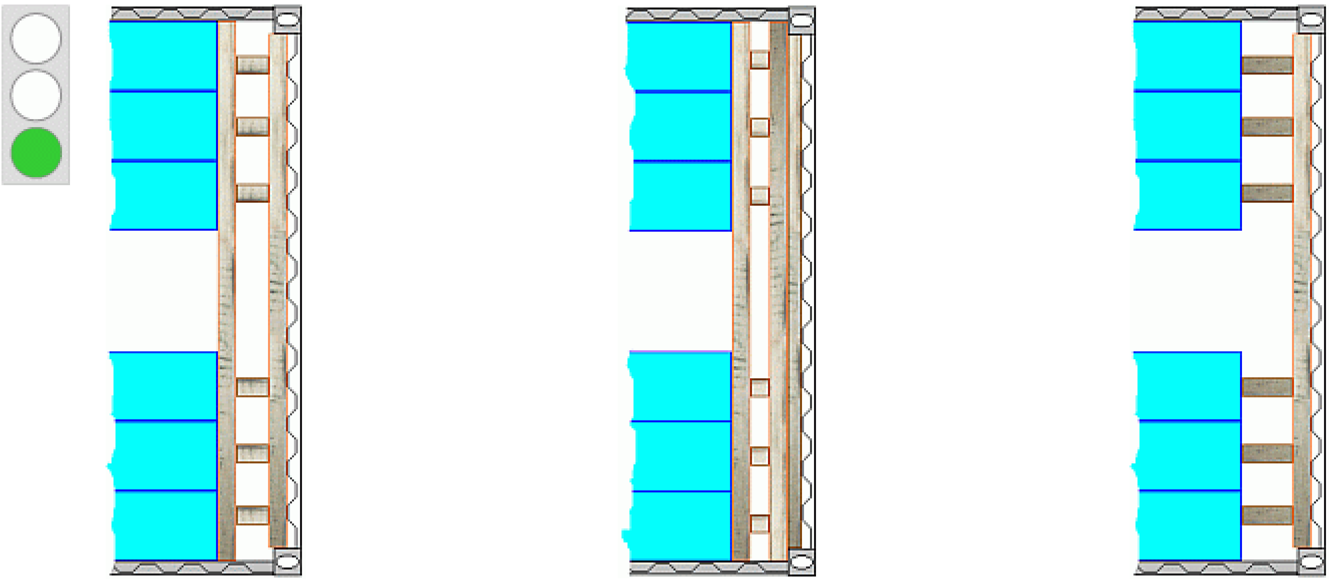
It is not necessary to secure the shoring members against shifting in the lengthwise direction if they are fitted directly into the container corrugations at the top. With smooth container walls, however, "X-bracing" in the lengthwise direction would be essential.

The round bars are now fixed in the crosswise direction in such a way that they can withstand any movements which will occur in transit:



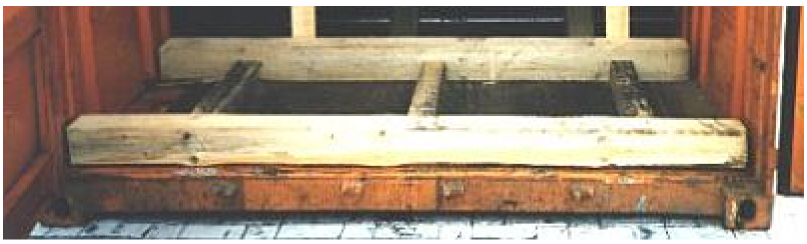
Effectiveness of shoring at a tilt of 45° to the side

Gaps in the door area must be filled with bracing to counter lengthwise movement. The method used is selected on the basis of the cargo mass, size of the gaps and similar factors.



Lengthwise bracing variants

This Figure shows bracing for moderate cargo weights:

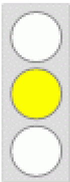


The lengthwise wooden members are 10 cm x 10 cm in size. A total cross-sectional area of 300 cm² is thus available which bears perpendicularly to the grain of the 14 cm x 14 cm crosspieces. On the basis of a rough calculation, the bracing can withstand a lengthwise load of 300 cm² lumber cross-section x 30 daN/cm² of cross-sectional area = 9,000 daN. If the lengthwise members had also been 14 cm x 14 cm in size, loading capacity would have been almost doubled: 3 x 14 cm x 14 cm x 30 daN/cm = 17,640 daN.

Example: Bundles of round bars and pipes in a 20' box container


Inadequate securing in the door area and in the vertical direction

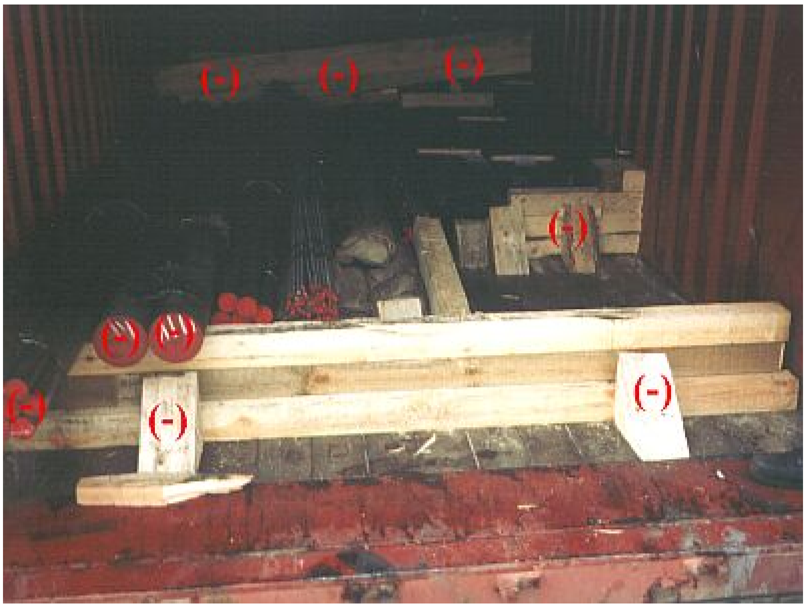
If this container is carried on a container ship in a fore and aft stow, the round bars could shift sideways, causing severe damage to the container and to adjacent containers. The shoring described in detail above would in that case be absolutely essential to secure the cargo. Since the simple steel wires used to bundle both the pipes and the round bars are incapable of keeping either the pipes or the round bars in the bundles, the wooden bracing in the door area must be raised to the height of the upper layers.




Greased pipes can "shoot" out of their bundles

Pipe bundles and similar cargoes should thus generally be braced up to their full height as they tend to "shoot" out of their bundles, with this risk being particularly pronounced with greased pipes.

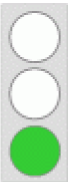
Example:
Round bars, bundled steel bars and profiles in a 20' box container



Inadequately secured cargo of steel

The wedges will be completely unable to withstand the anticipated lengthwise forces. The bundles and bars on the left are completely unsecured in the lengthwise direction. The wooden members in the background fitted between the corrugations cannot protect the cargo from vertical forces nor prevent it from shifting out of its layers on exposure to sideways stresses.

Example: Round bars in 20' box containers

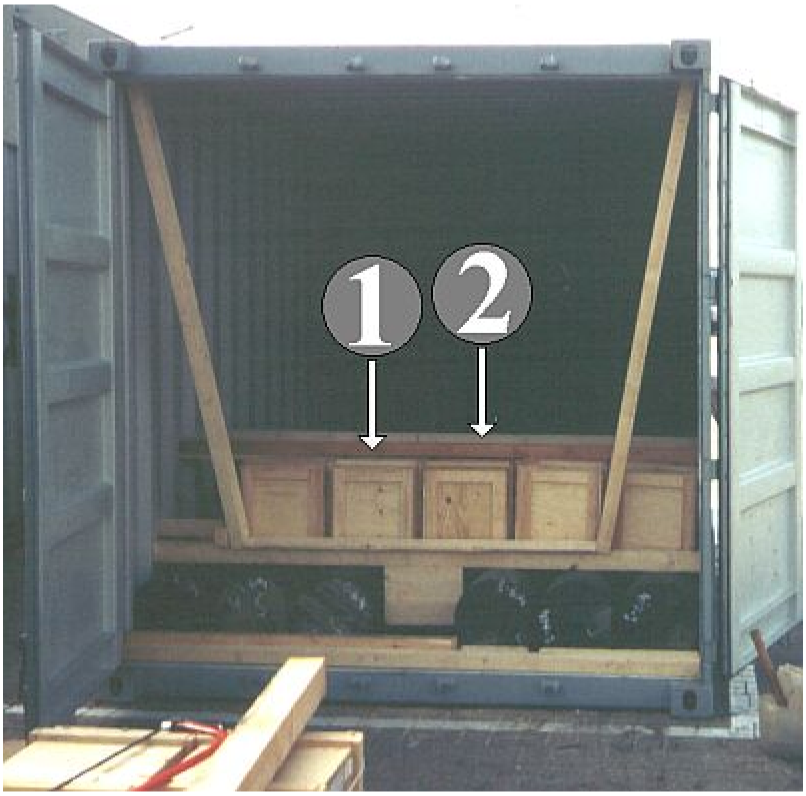


Shoring in the front of the container

These round bars, in contrast, are secured so that they cannot shift on exposure to sideways stresses and tilting.

Two shoring structures for six round bars

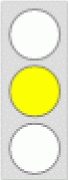
Example: Round bars and accompanying cases in a 20' box container

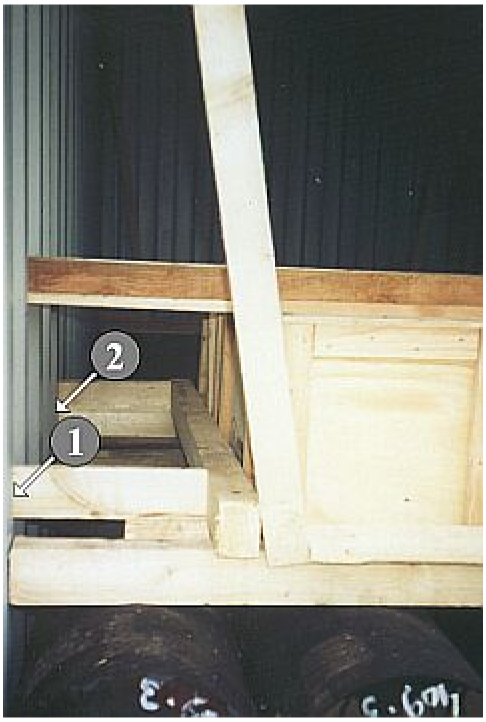


Appropriate cargo securing for round bars and wooden cases

The round bars are well secured. The cases are only light, so the securing provided by the wooden members (1) and (2) fitted tightly between the corrugations may be considered adequate. If the cases had been heavy, shoring would have been an appropriate way of securing the cases too.

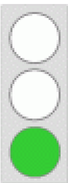
View of case securing to the rear

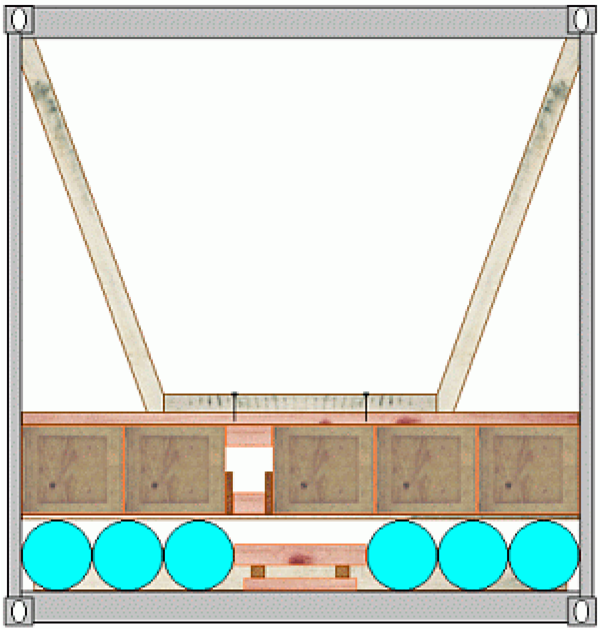




Detail

For light cases such as these, bracing with squared lumber against the container wall is sufficient. For heavier weights, boards or planks would have to be laid between the squared lumber members (1) and (2) and the container side wall.





Securing the entire cargo with shoring

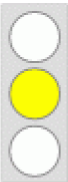
Appropriate securing could also have been achieved by loading the cases directly onto the round bars and securing the entire cargo with shoring. For this to be feasible, the cases must be sufficiently strong.

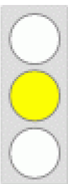
Example: Round bars and cases of hazardous materials in a 20' box container

Round bars of different weights and lengths in a 20' box container

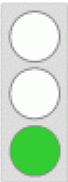
The round bars are adequately blocked relative to one another and to the end walls. The base members for the shoring, which is yet to be put in place, have already been laid.

The following Figures show the additional cases and how they are secured by nailed wooden fixings and bracing. Since these operations were not carried out ideally in the first Figure, a feasible loading variant is also provided.



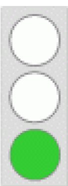


Adequate securing of round bars with small errors in securing the additional wooden cases.



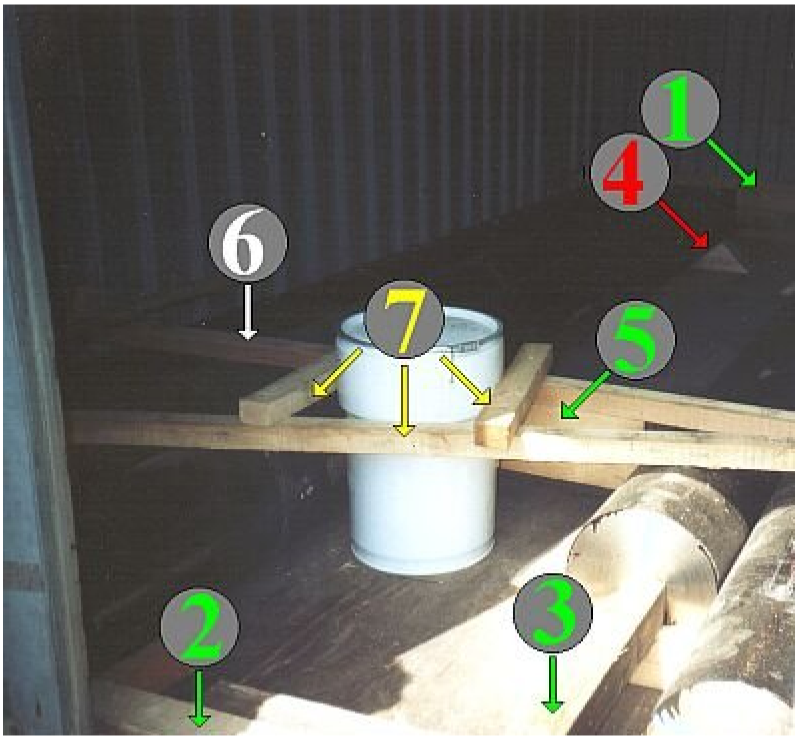
Possible securing variant using horizontally fitted wooden members

Wooden members fitted horizontally at the height of the cases' center of gravity prevent the cases from moving. It must be ensured that the boards, planks or squared lumber used for this purpose cannot slacken in transit. This can simply and effectively be achieved by wooden uprights, such as thin boards or laths.



Additional securing of horizontal wooden members

Example:
Round bars and paint bucket as accompanying cargo in a 20' box container

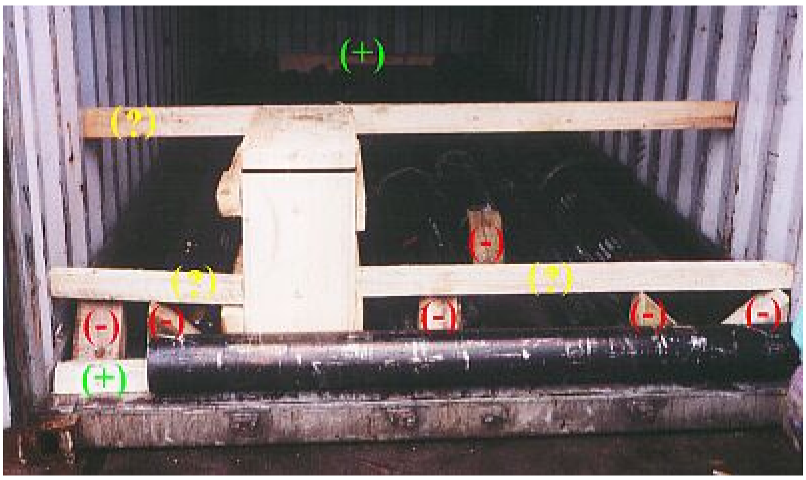


"Shadow and light" in securing

No criticism need be leveled at the lengthwise securing of the round bars by the wooden buffer members (1) against the front end wall and in the door area (2) nor at the lengthwise squared lumber member (3). The sideways securing by wedges (4) in the front part of the container is inadequate. Crosswise bracing must be provided here in a similar way to that provided with the wooden members (5). Securing for the paint bucket has been constructed from the squared lumber members (6) and (7), which is a somewhat unusual method. Despite considerable amounts of material being used, only little labor is involved, so the method is perfectly reasonable. The wooden member (6) has merely been forced into place between the container sides. The cargo is thus insufficiently secured and the overall securing action must be regarded as inadequate.

If the wooden member (6) were used as the base member for shoring and the same method were used in the front part of the container, the overall securing action could be described as good. The paint bucket could be tied to the wooden crosspieces and one of the shoring members.

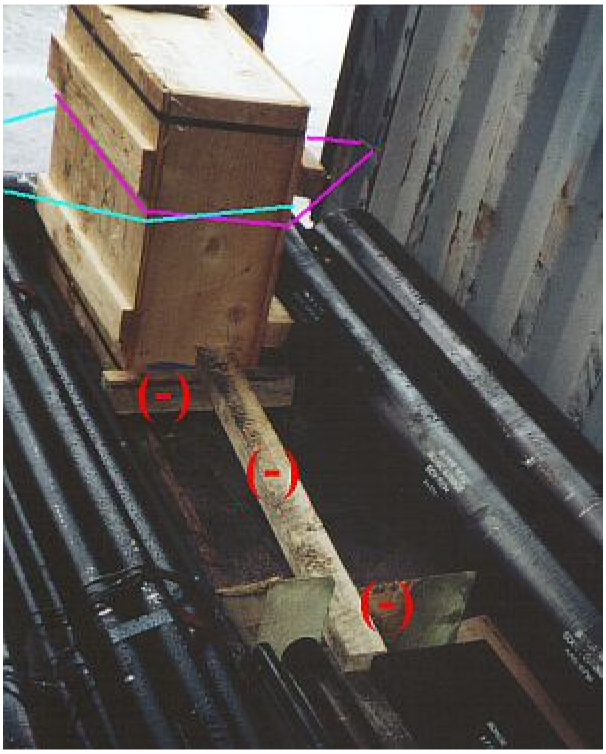
Example:
Round bars of different lengths and a wooden case as accompanying cargo



Above and left:
Overall inadequate cargo securing for round bars

Lengthwise movement of the round bars has been sufficiently restricted by wooden buffer members at the front end and a short round bar by the door. Lengthwise movement of the round bars is not prevented by the use of wedges. Vertical securing, which could simultaneously prevent sideways shifting, is absent, however.

The case is not satisfactorily secured.



Securing the case with loop lashings would have been a good idea.

The case could have been secured at the floor level of the gap with wooden members. Loop lashings from the left and right could have been provided to prevent tipping. If shoring had been used, the case could have been secured to one of the wooden shoring members.

5.2.14.11 Slabs - definition

Definition

Slabs are cuboid semi-finished steel products that are converted into sheet and strip products at the rolling mill.

Cakes are a cuboid semi-finished copper product that is used to make other semi-finished or finished products.

The securing methods used for these semi-finished products vary only slightly due to their different dimensions so no differentiation is made below.

Transport options

As in the past, this type of cargo remains particularly suitable for conventional shipment. If container transport is the only option, flatracks are the most suitable CTUs, as slabs can be set down most rapidly and secured most effectively on them. Since flatracks are not carried in certain seasons or there are no return cargoes for flatracks in some regions of service, open-top containers or entirely standard box containers are often used.

Stainless steel slabs in port storage

5.2.14.12 Slabs - line loads

Variation in loading and securing as a function of the dimensions and masses of the slabs

Transport options

In order better to clarify any differences in packing and securing, the following examples relate to the two slabs shown, which are of the following dimensions.

Upper slab:

Length	4,270 mm
Width	1,400 mm
Height	510 mm

Its mass is 23,160 kg (23.160 metric tons). An exact conversion reveals a weight-force or normal force of 227,199.6 newtons or 22,712 daN or 22.712 kN (23,160 kg x 9.81 m/s² = 227,199.6 newtons).

The line load of the slab can be determined by dividing its mass or weight by its length, so producing the following Figures:

Mass/weight	Length of slab	Line load
23,160 kg	4.27 m	5,423.888 kg/m
227.1996 kN	4.27 m	53.208 kN/m

Lower slab:

Length	3,100 mm
Width	1,400 mm
Height	710 mm

Its mass is 23,463 kg or 23.463 metric tons. An exact conversion reveals a weight-force or normal force of 230,172 newtons or 23,017.2 daN or 230.712 kN.

The line load of the slab can be determined by dividing its mass or weight by its length, so producing the following Figures:

Mass/weight	Length of slab	Line load
23,463 kg	3.10 m	7,568.710 kg/m
230.17203 kN	3.10 m	74.249 kN/m

In box containers the floor is constructed from the transverse bottom cross members with textured coated board or plywood sheet or plank flooring. Floors are intended to carry uniformly distributed loads.

The admissible line load of 20' containers is determined by dividing the admissible payload by the value obtained after subtracting 2 m from the container's length. A completely accurate calculation would require this value to be deducted from the container's loading length.
In rough terms, the admissible line load for 20' containers can be calculated by dividing payload by 4 m (approx. container length of 6 m minus 2 m).

Since older types of standard containers with a payload of approx. 18,000 kg have admissible line loads of only 4,500 kg/m, such containers cannot be used. Even special measures to distribute the pressure are of no assistance here as the mass of the cargo exceeds the container's payload.

However, any container having a payload or line load which matches or even exceeds the mass of the slab or the line load it applies may be considered.

The minimum container payload required for individual heavy cargoes can be calculated by multiplying the line load applied by the cargo by the reference size used for calculating the line load for the particular container length, i.e. 4 m for 20' containers:

The minimum container payload required to accommodate the upper of the above-stated stainless steel slabs may accordingly be calculated as follows:

Line load applied by slab	Reference length of container	Minimum required container payload
5,423.888 kg/m	4.00 m	21,695.552 kg
53.208 kN/m	4.00 m	212.832 kN

The calculation shows that no older type ISO containers can be considered, only newer types. Purely theoretically, older type 40' containers could be used to transport the slab as they have a payload of approx. 27 metric tons. However, since the admissible line loads of these containers are only approx. 3 metric tons/m, considerable quantities of material would be required for propping/load distribution. It is accordingly uneconomic to use 40' containers.

The minimum container payload required to accommodate the lower of the above-stated stainless steel slabs may accordingly be calculated as follows:

Line load applied by slab	Reference length of container	Minimum required container payload
7,568.710 kg/m	4.00 m	30,274.840 kg
74.249 kN/m	4.00 m	296.996 kN

The calculation shows that, at the time of loading, neither older type ISO containers nor newer type 20' containers could be considered for this slab, as there was at that time no commercially available 20' box container with a payload of more than 30 metric tons.

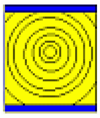
Purely theoretically, newer type 40' containers could have been used to transport the slab as some would have the necessary payload. However, since the admissible line loads of these containers are only approx. 3.3 to 3.5 metric tons/m, even greater quantities of material would be required for propping or for load distribution than for the "upper slab". For these reasons, box containers cannot be used to carry the "lower slab".

5.2.14.13 Slabs - load distribution on flatracks

Packing the "short slab" on a 20' flatrack

The flooring of flatracks is also designed to be uniformly loaded. However, unlike in box containers, loads can very readily be distributed on the strong bottom side rails of flatracks. This requirement presents no problems for cargo handling. If this requirement is met, no problems will arise with using either lifting gear or ground conveyors, such as forklift trucks.

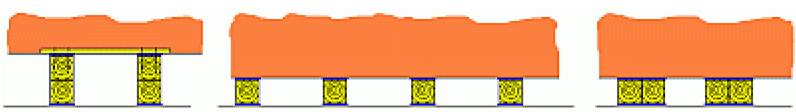
In order to minimize the costs involved in securing, friction forces should be maximized. Using "sandwich" supports made from squared lumber with strips of friction-enhancing material laid on top and beneath is one way of achieving this.



Sandwich support of the structure "friction-enhancing mat/wood/friction-enhancing mat"

The friction-enhancing material used should comprise non-slip mats with a coefficient of sliding friction stated by the manufacturer of at least μ = 0.6. In the case of the large masses being loaded in the example, it must be borne in mind that, given the relatively small contact areas and consequently high pressures, the coefficient of friction will be reduced due to material compaction. It is not unusual for the coefficient of sliding friction to fall, for example, from μ = 0.6 to μ = 0.40. Accordingly, only the lower value should be used for calculation purposes. If contact areas are very small, the coefficient of sliding friction could drop even further. For this reason, supports with an excessively small surface area must not be used.

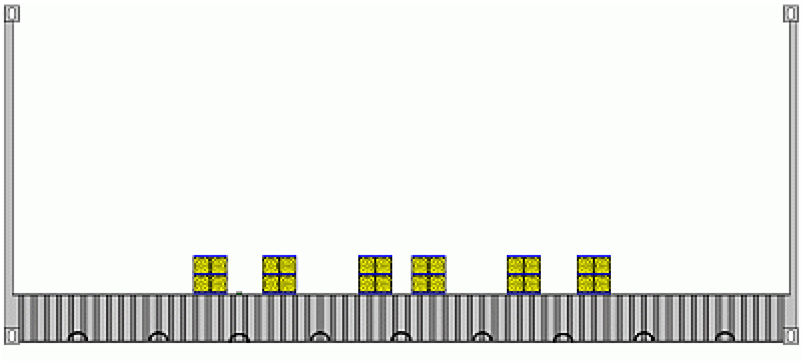
The greater the height of the selected support relative to its contact area, the greater are the forces which can be transferred into the load-bearing components (in the present case, the bottom side rails of the flatrack), but the greater too is the risk of tipping. Obviously, the opposite also applies: the smaller the height of the selected support relative to its contact area, the smaller are the forces which can be transferred into the load-bearing components of the means of transport, but the smaller too is the risk of tipping.

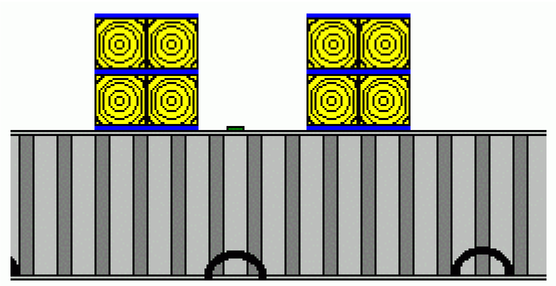


Different heights of sandwich supports at greater or lesser risk of tipping

To maximize efficiency of operation, the necessary strength of the supports and thus their dimensions should be roughly calculated before loading. Anticipated shipping stresses and the best cargo securing methods are also determined. Once these parameters have been established, material strengths can be determined in accordance with the available lashing points and load-bearing components of the container.

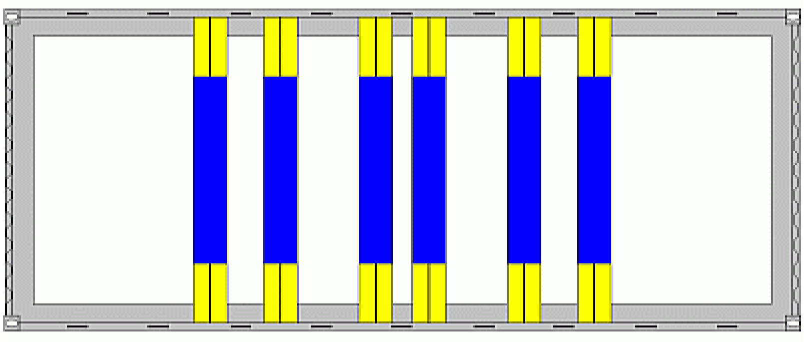
In the present case, 14 cm x 14 cm squared lumber supports are selected and laid in pairs side by side and one on top of the other, so producing a high support and minimizing the risk of tipping, for example when the cargo is laid down. In order to minimize cargo securing effort, these supports are provided with strips of 10 mm thick non-slip mats to make "sandwich" supports.





Above and selective enlargement to the left:

Side view of "sandwich" support consisting of 14 cm x 14 cm squared lumber and strips of 10 mm thick friction-enhancing material



Plan view of "sandwich" support consisting of 14 cm x 14 cm squared lumber and strips of 10 mm thick friction-enhancing material, arranged in a block of four

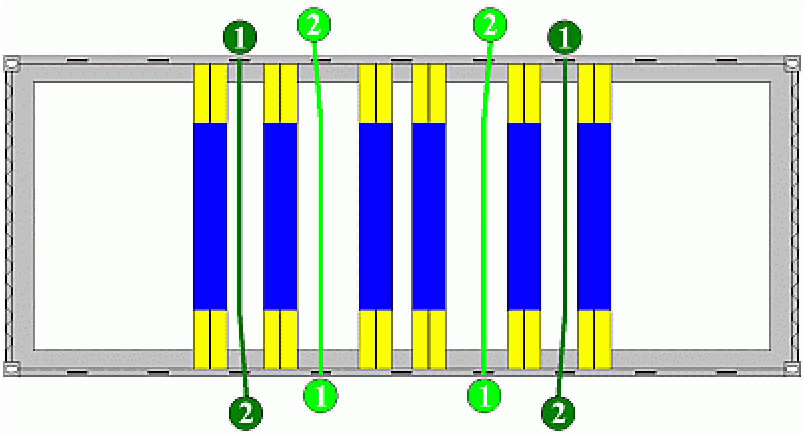
The choice of 14 cm x 14 cm squared lumber and the manner in which they are arranged produces twelve squared lumber "beams", each of a height of 28 cm, which bear on the side rails of the flatrack. Due to compression by the heavy slab, the coefficient of sliding friction is assumed to be μ = 0.4.

5.2.14.14 Slabs - securing - lateral

Shipping stresses are assumed to be 0.8 g in the sideways direction and 1.0 g in the lengthwise direction. The difference between these values and μ = 0.4 must be made up by additional securing. It is decided to provide only tight-fit securing. Sideways securing will be provided by "loop lashings" (half loops). There are two options for lengthwise securing:

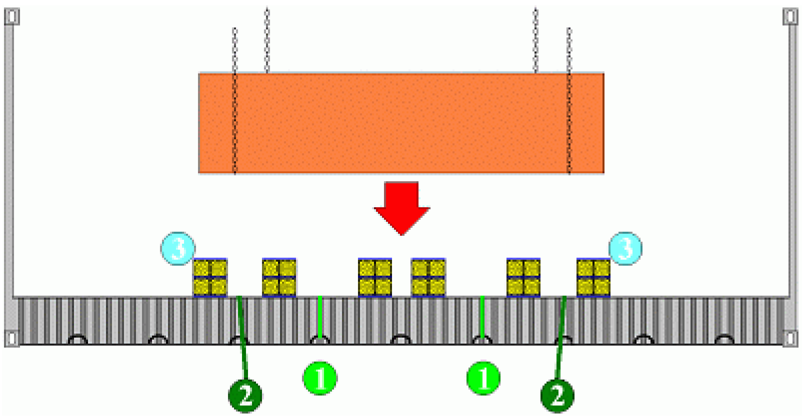
- If the end walls are sufficiently strong, bracing is enough.
- If the end walls are weaker, the necessary securing forces can be achieved by a combination of bracing and lashing.

The sideways lashings are prepared before the cargo is set down:



Initial attachment and arrangement of loop lashings

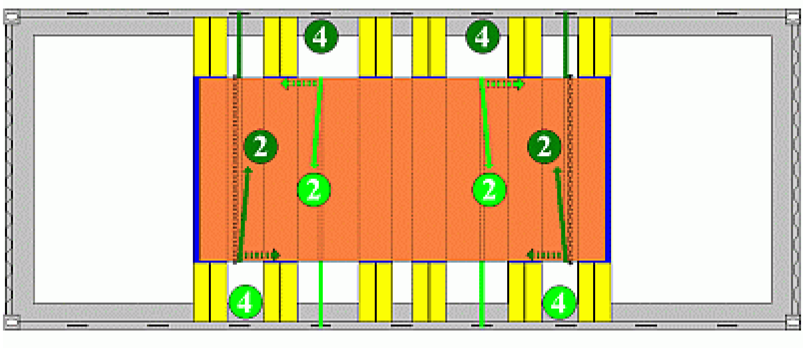
The lashing materials used, such as steel strapping, wire ropes, chains or the like, are attached to the lashing points (1) and the other ends are passed over to the opposite side (2), where they are laid down loose. For the slab which is to be secured, each loop lashing will require a length of approx. 5 m plus a little extra, the length of which will be determined by the materials used and how they are tensioned. The outermost crosswise supports, labeled (3) in the following diagram, at each end should in each case be laid so that they extend beyond the slab in the direction of the end wall. In this way, these wooden crosspieces can act as an abutment for the bracing towards the end walls of the flatrack.



Setting down the slab:

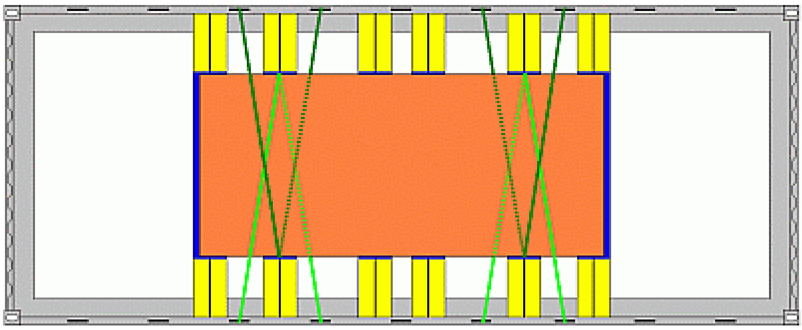
(1) = attached ends of the loop lashings
(2) = loose ends of the loop lashings
(3) = wooden crosspieces protruding towards the end walls

Once the cargo has been set down, the loose ends of the lashings (2) are each passed over the slab to the lashing points (4) on the other side of the flatrack. Before finally fastening the ends to these lashing points, the path taken by the loop lashings must be carefully checked. At the deflection points shown by the dotted arrows in the following diagram, the lashing means must be adjusted manually, preferably by a second person, so that the parts of the loop lashing running above and below the slab are symmetrical. In simple terms, the shortest path between the lashing points must be chosen. At no point during transport must it be possible for the lashing materials to shift or move of their own accord.

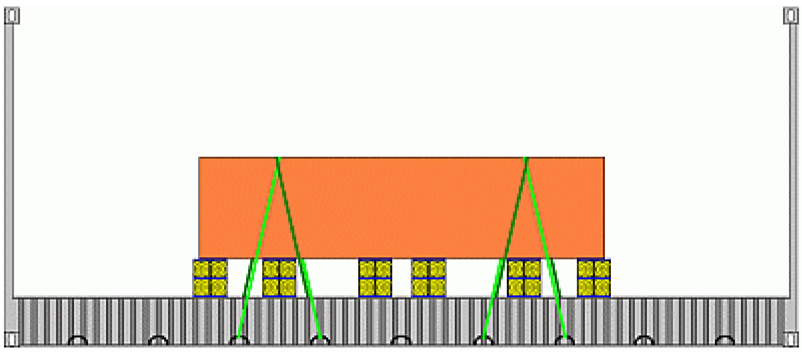


Positioning and fastening of loop lashings

Once properly fastened, the loop lashings look like this:

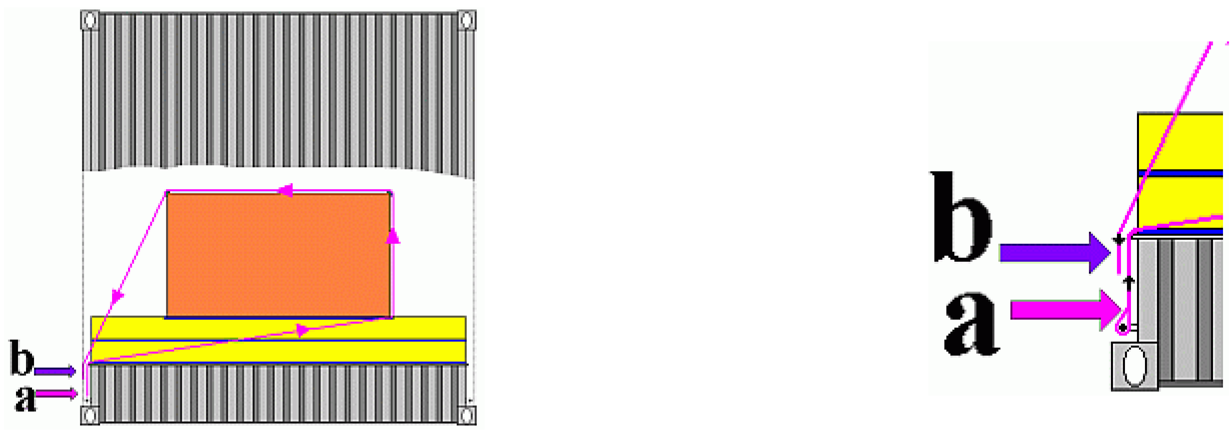


Plan view - slab secured with two loop lashings on each side



Side view - slab secured with two loop lashings on each side

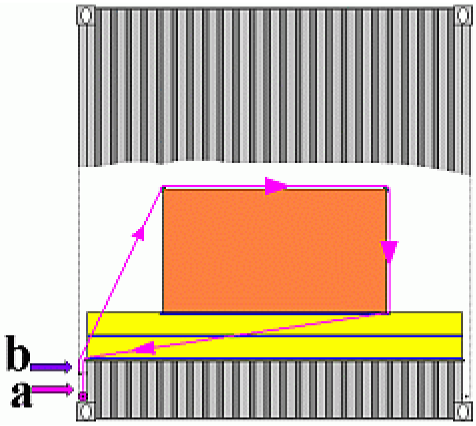
The path taken by the loop lashings is clarified again in the following Figure:

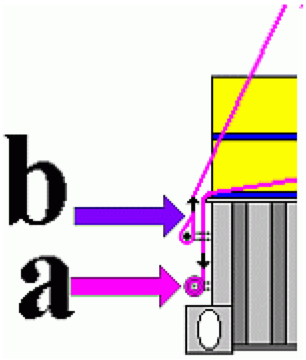


Front view - path of a loop lashing to one side

Point a is the initial attachment point for all conventionally used cargo securing materials such as steel strapping, steel wire ropes, chains and "single-use" belts as well as prefabricated cargo securing materials such as lashing belts with ratchet tensioners, chains with integral tensioners etc. The loop lashing is passed from point a beneath the item of cargo to be secured. As already mentioned, this end is advantageously positioned before the item of cargo is loaded. Point b represents an adjacent lashing point with an identical or at least similar maximum securing load. The end of the loop lashing which has been passed over the cargo is attached to this point. When tighteners are used, they are attached to point b either directly or by means of additional aids.

If the lashing means, such as for example wire or belt reels, are an integral part of the flatrack or similar means of transport, there are two basic securing methods:





Front view - path of a loop lashing to one side

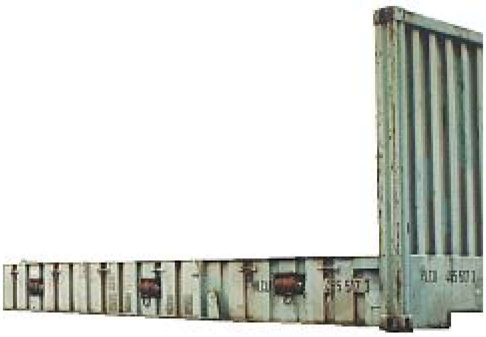
The belts are unwound from the reels and passed over to the other side. Once the cargo has been loaded, they are hooked on to the opposite side and tightened. As a result, tension is applied from below in this case. Of course, if desired, tension may also be applied from above. However, in this case, the cargo must first be loaded. The belts should then be passed over the slab, then returned to the same side under the slab and hooked in on that side. Clearly, this method is somewhat more awkward and time-consuming.

Using the quicker method, lateral securing of the slab would entail:

- positioning sandwich supports crosswise on the flatrack
- unrolling two belts from each side and pulling them over to the other side of the flatrack
- setting down the slab on the flatrack
- throwing the belts back over the slab to the starting side and hooking them into a load-bearing lashing point, taking care to ensure that the belts are not twisted and to pad sharp edges
- and finishing the job by tightening the ratchet tensioners.

Due to design shortcomings, this ideal type of securing is currently not yet possible.

Lashing reels arranged on only one side of the flatrack are not entirely suitable for providing securing with loop lashings.



Flatrack with integral lashing reels and webbing belts

In this case, using one of the methods described above, tension may be applied from above or below with the lashing reels on one side. If possible, webbing belts of the same maximum securing load and tightenable with conventional ratchet tensioners should be used to provide securing to the other side. If such tighteners are not available, it is also entirely feasible to use equivalent single-use belts which are pretensioned by special tighteners.

5.2.14.15 Slabs - maximum securing load of lashing points

So that the good securing performance offered by loop lashings may in future be better utilized, container manufacturers should pay greater attention to cargo securing and install such aids on both sides of the container, while those commissioning containers should specify that such aids be fitted. In this way, one of the very best lashing methods, namely loop lashing, can be implemented particularly cost-effectively.

Effective securing forces can be calculated from material strengths and lashing angles. The strength of lashing points is sometimes shown on flatracks.

While the meaning of "safe working load" is clearly defined for load suspension devices in hoist operation and loading gear, it is not for lashing points on containers.

And what are packing personnel to make of "maximum pull strength"? The "Guidelines for the correct stowage and securing of cargoes for carriage in ocean-going ships" provide, in particular in Appendix 13, information about nominal breaking load (BL) and maximum securing load (MSL).

If no information is provided on CTUs with regard to the strength of lashing points, or if such information is unclear, the rules of thumb published in the above guidelines should be applied.

The breaking load of lashing rings or bars etc. may be calculated using the rule of thumb $d^2 \times 20$, i.e. diameter x diameter x 20. The maximum securing load (MSL) should amount to at most 50% of the breaking load. The result of this rough calculation is a value in kN if the diameter unit used is centimeters and in daN if the diameter unit used is millimeters: In accordance with the above explanations, maximum securing load is accordingly half the nominal breaking load (BL), i.e. MSL = BL/2.

Determining the diameter of lashing points

If the diameter of a lashing point is measured as 2 cm or 20 mm, the nominal breaking load (BL) can be calculated as follows:

$$BL = d \times d \times 20 = 2 \times 2 \times 20 = 80 \text{ [kN]}$$
$$BL = d \times d \times 20 = 20 \times 20 \times 20 = 8{,}000 \text{ [daN]}$$

Since the MSL can amount to at most half the BL, the MSL is determined as follows:

$$MSL = BL/2 = 80/2 = 40 \text{ [kN]}$$
$$MSL = BL/2 = 8{,}000/2 = 4{,}000 \text{ [daN]}$$

The flatrack loaded with the slab has lashing points 20 mm in diameter. Using the two loop lashings, it is possible to achieve lashing forces (in relation to the lashing points) in each sideways direction of 4 × 40 kN = 160 kN or 4 × 4,000 daN = 16,000 daN. This is entirely sufficient because with a mass of 23,463 kg or a normal force of 230,172 N and assuming sideways acceleration of 0.8 g and a coefficient of sliding friction of $\mu = 0.4$, securing forces of 92,065 N must be applied; these amount to 9,206.5 daN or 92.065 kN.

Obviously, in this case, the maximum securing load can be calculated without passing via the nominal breaking load. The maximum securing load of lashing points can be calculated from the rule of thumb $d^2 \times 10$, as the MSL may at most be only half the BL. The calculation is then as follows:

$$MSL = d \times d \times 10 = 2 \times 2 \times 10 = 40 \text{ [kN]}$$
$$MSL = d \times d \times 10 = 20 \times 20 \times 10 = 4{,}000 \text{ [daN]}$$

This simplified calculation can be used whenever the ratio between BL and MSL is a round number, otherwise it is always better to calculate the BL first and then the MSL.

5.2.14.16 Securing with steel strapping

The example uses 32x16 blued steel strap, i.e. steel strapping of a width of 3.2 cm or 32 mm and a thickness of 0.16 cm or 1.6 mm, because when specifying steel strap, the first number is the width in millimeters and the second number the thickness in tenths of a millimeter. The "Guidelines for the correct stowage and securing of cargoes for carriage in ocean-going ships" provide the following rule of thumb for the nominal breaking load (BL) of blued steel strap: width x thickness x 85. The maximum securing load should amount to at most 70% of the BL, so giving the following calculations:

$$BL = b \times d \times 85 = 3.2 \times 0.16 \times 85 = 43.52 \text{ [kN]}$$
$$BL = b \times d \times 85 = 32 \times 1.6 \times 85 = 4{,}352 \text{ [daN]}$$

Since the MSL can amount to at most 70% of the BL, the MSL is determined as follows:

$$MSL = BL \times 0.7 = 43.52 \times 0.7 = 30.464 \text{ [kN]}$$
$$MSL = BL \times 0.7 = 4{,}352 \times 0.7 = 3{,}046.4 \text{ [daN]}$$

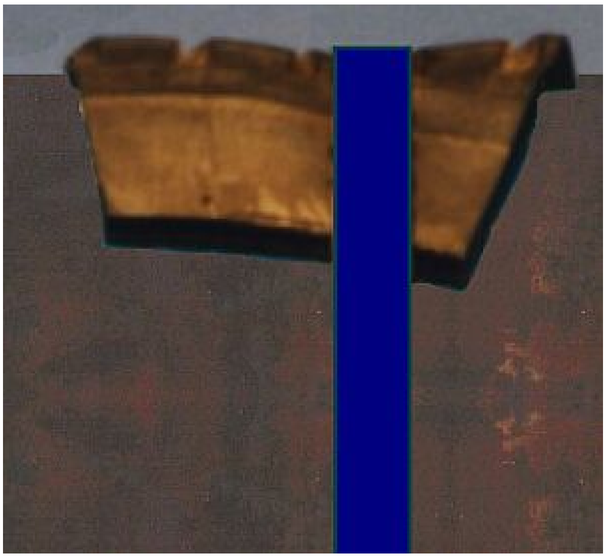
Steel strapping of the stated quality and type is sufficient to provide lateral securing of the slab. The four working parts of the two loop lashings on each side could theoretically provide a securing force of 121.856 kN or 12,185.6 daN. Even if the effective forces are assumed to be reduced to a certain extent due to the lashing angle, securing will be adequate.

Steel strapping can only be used for securing if the lashing points are suitable for this purpose, i.e. they must have straight portions of sufficient width for the entire width of the steel strap to lie against. Unsuitable lashing points are those in which the steel strap does not lie flat over its width and, when subjected to tension, is bent in the transverse direction.


Lashing point suitable for steel strapping


Lashing point unsuitable for steel strapping

Advantages of steel strapping are that it can be applied very cheaply and it is relatively strong. Disadvantages, however, are its very low elasticity and the impossibility of retensioning. When applying steel strapping, it is thus advisable to combine it with an elastic material and segments of used tires are suitable for this purpose. This markedly increases the elasticity of the overall lashing and the tire rubber also provides excellent edge protection.



Securing a slab with steel strapping

5.2.14.17 Slabs - maximum securing load of wire ropes

Steel wire rope lashing is another option, for example wire ropes of the type 6 x 37 + 1 FC in conjunction with suitable shackles and turnbuckles would be a usable alternative.

The "Guidelines for the correct stowage and securing of cargoes for carriage in ocean-going ships" provide the following rule of thumb for calculating the nominal breaking load (BL) of steel wire ropes of the stated type: BL = 50 x d^2.

The basic calculations for 10 mm thick wire ropes are as follows:

BL = d x d x 50 = 1 x 1 x 50 = 50 [kN]
BL = d x d x 50 = 10 x 10 x 50 = 5,000 [daN]

The basic calculations for 12 mm thick wire ropes are as follows:

BL = d x d x 50 = 1.2 x 1.2 x 50 = 72 [kN]
BL = d x d x 50 = 12 x 12 x 50 = 7,200 [daN]

Since the regulations state that the maximum securing load for "single-use wire ropes" can be assumed to be only 80% of the breaking load, the MSL of the above-described lashing wire ropes can be calculated as follows:

For 10 mm diameter wire ropes:

MSL = BL x 0.8 = 50 x 0.8 = 40 [kN]
MSL = BL x 0.8 = 5,000 x 0.8 = 4,000 [daN]

For 12 mm diameter wire ropes:

MSL = BL x 0.8 = 72 x 0.8 = 57.6 [kN]
MSL = BL x 0.8 = 7,200 x 0.8 = 5,760 [daN]

A direct rule of thumb can be used to calculate the MSL of "single-use wire lashing ropes" from the above-stated values without having to calculate the BL. Since the MSL can amount to at most 80% of the BL, the rule of thumb for the MSL of "single-use wire lashing ropes" is:

MSL = d^2 x 40

The direct calculation using the rule of thumb for 10 mm wire ropes would thus have been:

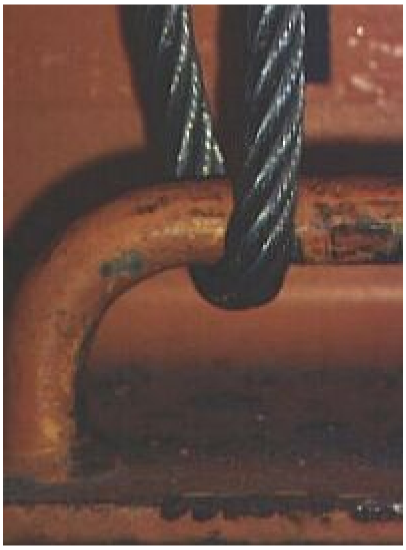
MSL = d x d x 40 = 1 x 1 x 40 = 40 [kN]
MSL = d x d x 40 = 10 x 10 x 40 = 4,000 [daN]

The maximum securing load of 12 mm wire ropes could have been calculated as follows:

MSL = d x d x 40 = 1.2 x 1.2 x 40 = 57.6 [kN]
MSL = d x d x 40 = 12 x 12 x 40 = 5,760 [daN]

The calculated strengths apply per single run of the particular rope and should be multiplied appropriately for multiple runs of the rope. A note of caution must be sounded, however, as wire ropes are weakened by deflection around lashing points, shackles, turnbuckles or other fastening elements, the extent of which weakening being greater, the smaller is the ratio of diameter of deflection D to rope diameter d.

D/d ratio	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**
Strength per single run	50%	65%	72%	77%	81%	85%	89%	93%	96%	99%



Example of weakening of a wire rope of 16 mm diam. on deflection around a lashing point of 20 mm diam. and example of nonuniform securing

The lashing point has a diameter of D = 20 mm, the wire rope of d = 16 mm.

The D/d ratio is 20 mm / 16 mm = 1.25.

On the basis of the Table, strength per single run can be calculated as approx. 68% that of the single run.

On the basis of the above-stated rules of thumb, the theoretical nominal breaking load of the doubled, 1.6 cm or 16 mm diam. wire rope is thus

$1.6 \times 1.6 \times 50 \times 0.68 = 87.04$ kN or
$d^2 \times 50 \times 0.68 = 16 \times 16 \times 50 \times 0.68 = 8{,}704$ daN

Since the MSL of "single-use wire ropes" can amount to at most 80% of the BL, the maximum securing load of the doubled wire rope is

87.04 kN x 0.8 = 69 kN or
8,704 daN x 0.8 = 6,963.2 daN.

The MSL of the 20 mm diam. lashing point is 50% of the BL, i.e. $d^2 \times 20 \times 0.5$.
Depending upon whether the result is required in daN or kN, the calculations are as follows:

$$MSL = d^2 \times 20 \times 0.5 = 2 \times 2 \times 20 \times 0.5 = 40 \quad [kN]$$
$$MSL = d^2 \times 20 \times 0.5 = 20 \times 20 \times 20 \times 0.5 = 4{,}000 \quad [daN]$$

Since the doubled wire rope has a substantially greater loading capacity than the lashing point to which it is attached, material was wasted in this case. Applying 16 mm wire rope securing to a 20 mm lashing point is nonuniform and uneconomic.

However, as the following Table shows, this does not only apply to the 16 mm wire rope. With the 20 mm diameter lashing point in question, it is only economic to use the 8 mm diameter "single-use wire lashing ropes", because in this case the maximum securing load of the double run virtually matches the maximum securing load of the lashing point. Smaller diameters of rope do not fully utilize the strength of the lashing point, while larger diameters do not fully utilize the strength of the wire lashing ropes.

Rope diam-eter [mm]	**Breaking load of a double run**	**Percent-age MSL of BL**	**Ratio of lashing point & wire diam.**	**Residual strength after deflection**	**MSL of double run taking account of deflection**
d	2 × d² × 50	80%	D/d	as per Table	Rule of thumb [in kN]
6	2 × 0.6 × 0.6 × 50	0.8	20/6 = 3.33	approx. 87%	25.056
8	2 × 0.8 × 0.8 × 50	0.8	20/8 = 2.50	81%	41.472
10	2 × 1.0 × 1.0 × 50	0.8	20/10 = 2.00	77%	61.600
12	2 × 1.2 × 1.2 × 50	0.8	20/12 = 1.66	approx. 74%	85.248
14	2 × 1.4 × 1.4 × 50	0.8	20/14 = 1.43	approx. 71%	111.328
16	2 × 1.6 × 1.6 × 50	0.8	20/16 = 1.25	approx. 68%	139.264

In the case of reusable wire lashing ropes, the "Guidelines for the correct stowage and securing of cargoes for carriage in ocean-going ships" state that the maximum securing load may be deemed to be only 30% of the nominal breaking load.

The following Table states MSL values for various thicknesses and deflections of such wires:

Rope diam-eter [mm]	**Breaking load of a double run**	**Percent-age MSL of BL**	**Ratio of lashing point & wire diam.**	**Residual strength after deflection**	**MSL of double run taking account of deflection**
d	2 × d² × 50	30%	D/d	as per Table	Rule of thumb [in kN]
6	2 × 0.6 × 0.6 × 50	0.3	20/6 = 3.33	approx. 87%	9,396
8	2 × 0.8 × 0.8 × 50	0.3	20/8 = 2.50	81%	15.552
10	2 × 1.0 × 1.0 × 50	0.3	20/10 = 2.00	77%	23.100
12	2 × 1.2 × 1.2 × 50	0.3	20/12 = 1.66	approx. 74%	31.968
14	2 × 1.4 × 1.4 × 50	0.3	20/14 = 1.43	approx. 71%	41.748
16	2 × 1.6 × 1.6 × 50	0.8	20/16 = 1.25	approx. 68%	52.224

Clearly, according to this Table, only the use of 14 mm diameter "multiple-use wire ropes" makes sense.

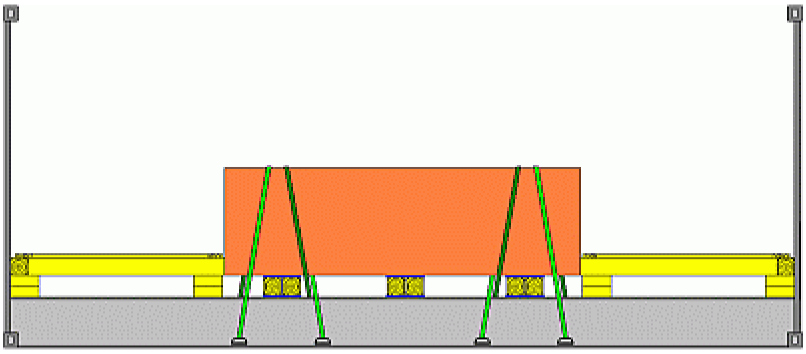
"Sharp edges" bring about a particularly marked reduction in the strength of steel wire ropes. Appropriate protective measures are thus very highly advisable.

Edge protection for wire ropes on a slab provided by a tire segment

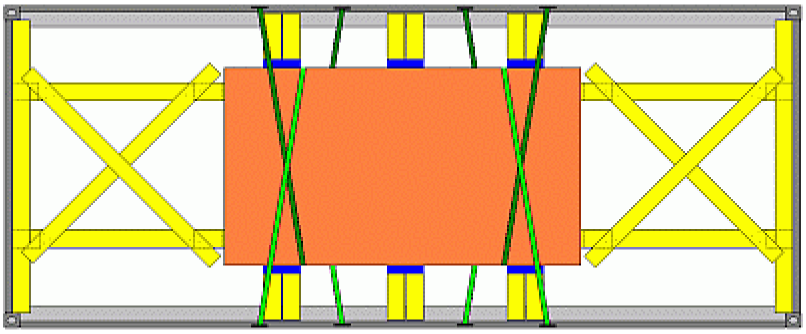
Wire ropes can be applied in various different ways. These various methods require the use of different strengths/thicknesses of materials and different kinds of aids.

5.2.14.18 Slabs - longitudinal securing by bracing

Wooden bracing is ideal for providing lengthwise securing of slabs.



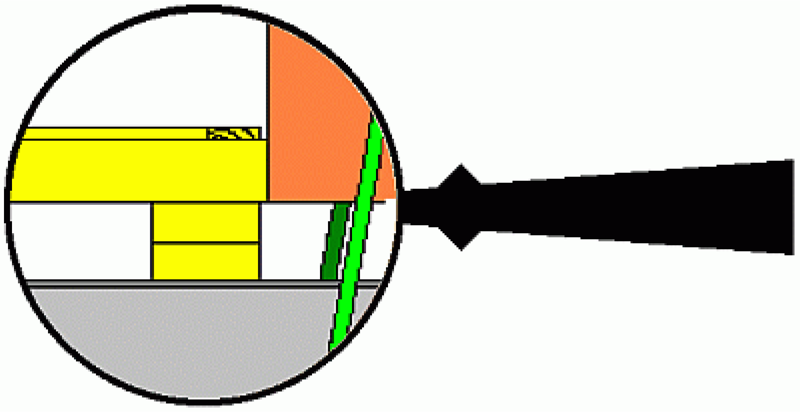
Lengthwise bracing of a slab - side view



Lengthwise bracing of a slab - plan view

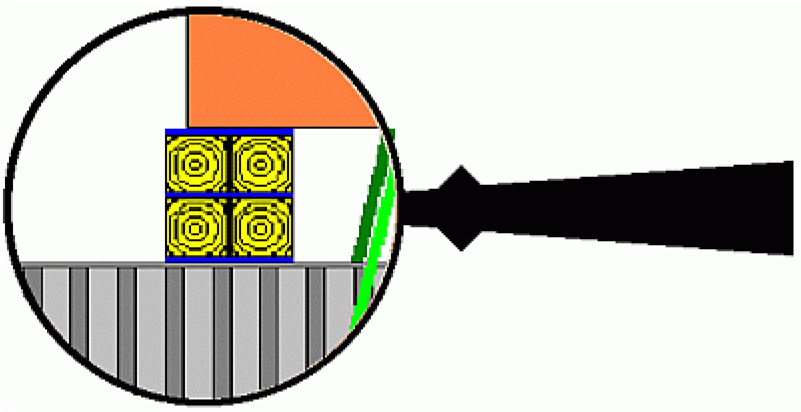
The drawings show the basic principles of lengthwise securing by means of wooden bracing. The essential components comprise the crosswise wooden members laid against the end walls to distribute pressure, longitudinal wooden members to absorb forces together with additional diagonally arranged wooden boards fastened with nails to provide "X-bracing". Some features should nevertheless be borne in mind. There are also various useful hints which can save materials.

It can be seen from the side view that the lengthwise wooden members are in each case firred at both ends.



Firring of lengthwise wooden members

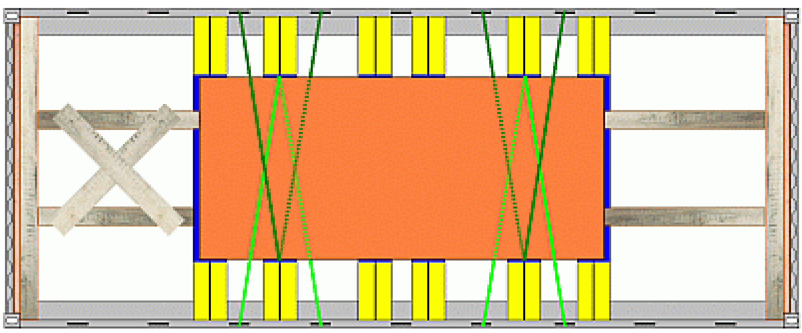
It has already been mentioned that it is advantageous, when placing the supports prior to loading of the slab, to ensure that these supports protrude a little at the sides.



Protruding supports save labor

The principal advantage is that firring need only be provided at the end walls of the flatrack.

Bracing for the slab could now be as below:

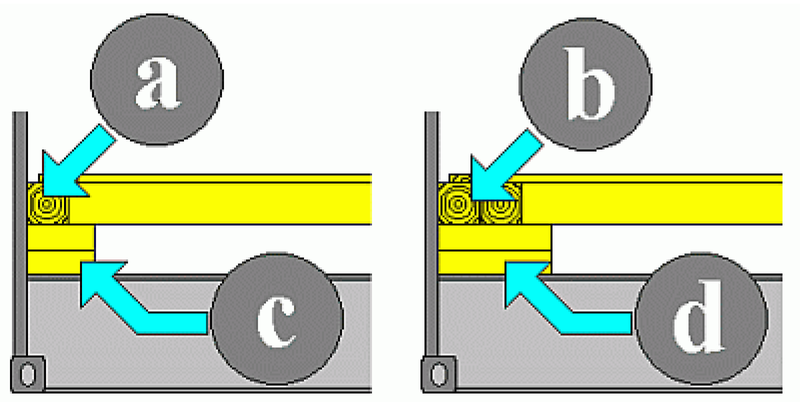


Wooden bracing - plan view

Whether or not the lengthwise members have to be X-braced is determined by the span, lumber cross-section and similar factors. In this case, 14 cm x 14 cm squared lumber of a length of just over 1.20 m was selected. No sagging or shifting is to be expected if the squared lumber members are attached to their firring. It is thus possible completely to dispense with X-bracing.

Each 14 cm x 14 cm squared lumber member can withstand bracing loads of approx. 6,000 daN. Two can thus withstand approx. 12,000 daN. Four wooden members of this size would accordingly be required to provide proper bracing.
(Specifically: 14 cm x 14 cm x 30 daN/cm² = 5,880 daN per wooden member)

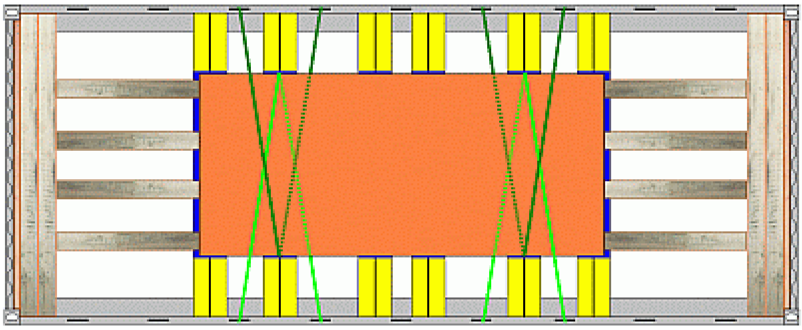
In order to ensure more reliable transfer of forces, the depth of the crosspieces in front of the flatrack end walls should be increased.



Increasing depth with a second wooden crosspiece

To this end, a second squared lumber member (b) is laid in front of (a). Longer firring may possibly be required for this purpose, in which case length (d) will be required instead of (c).

The slab is now secured against all eventualities in the lengthwise direction by the four wooden lengthwise members.



5.2.14.19 Slabs - packing into a box container

Packing a 23 metric ton stainless steel slab in a 20' box container

Introducing such a weight into a standard box container entails the use of particularly heavy equipment.

Introducing a 23 metric ton slab using a 35 metric ton forklift truck

In this case, a 35 metric ton forklift truck, which is capable of lifting the slab lengthwise, is being used and will set the slab down in the door area of the container. A 25 metric ton forklift truck would not be capable of picking up the slab in this way as the load-carrying capacity of 25 metric tons relates to a load center distance of 600 mm.

The slab must be positioned in such a way that, once it has been pushed into place, it will lie as centrally as possible in the container. During the initial phase, relatively small corrections to the starting position are possible from the side.
Squared lumber supports are intended to ensure that the slab lies as horizontally as possible and at the height of the container floor.

Correcting slab position in the container door area

The container to be packed should itself be immobilized as far as possible before the slab is pushed in.

Setting down the slab in the container door area

Friction-enhancing materials cannot be laid under the cargo in such cases. Not only would packing be complicated, but unpacking of the container would be made virtually impossible. The slab must be pushed in extremely carefully so that the sharp edges do not damage the container floor.

5.2.14.20 Slabs - lateral securing

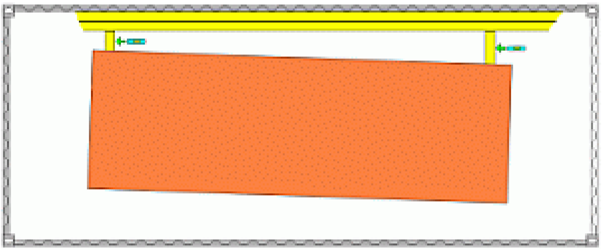
Since standard box containers do not have a sufficient number of adequately dimensioned lashing points to withstand the necessary securing forces, wooden blocking must be used. Several variants are presented below.

While exactly central placement of the slab in the container is theoretically desirable on load distribution grounds, it is not desirable with regard to the securing measures to be carried out.

All the squared lumber members for lateral and lengthwise bracing ought to be cut exactly to size.

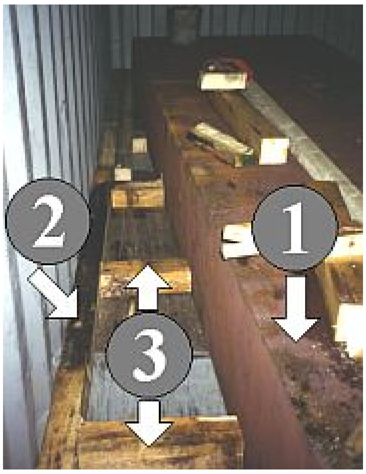
Exact positioning of the slab entails cutting the wood exactly to size.

However, if the slab is introduced with a slight offset (which almost always happens anyway when the slab is pushed in), the wooden bracing members need not be cut so exactly. An appropriate number of members ranging in size from the smallest to greatest distance between the slab and the container walls is cut to length and each member can then be "braced in place". The diagrams deliberately exaggerate the offset somewhat in order to clarify the principle.



Slab inserted with offset in order to permit more effective blocking

If it is assumed that the slab will be exposed in transit to sideways inertia forces amounting to 80% of its normal force and that friction forces of 20% of its normal force will apply, securing must be provided for 60% of the normal force. Since, given a uniform load distribution, the container walls are capable of withstanding 60% of the payload, this value is a good match for the required securing forces.

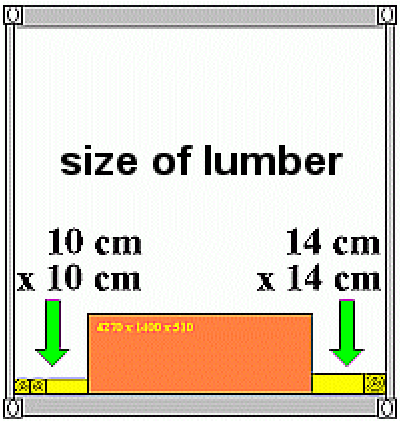


Lateral securing of a slab with 14 cm x 14 cm squared lumber

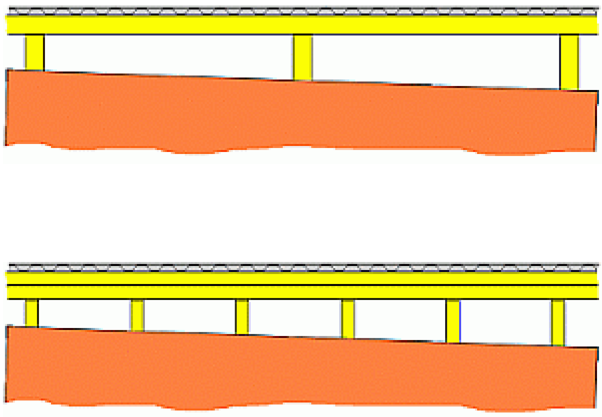
Key to reference numerals:
1 = slab
2 = squared lumber to distribute pressure
3 = squared lumber fixed to container floor for bracing

In this case, 14 cm x 14 cm squared lumber was used. If the price per cubic meter of lumber is identical, twice the length of 10 cm x 10 cm wooden members can be used.

The depth of the members for transferring forces to the container side walls can be improved in this way. If two 10 cm x 10 cm wooden members are positioned in each case against the container side walls instead of the singly positioned 14 cm x 14 cm wooden members, this depth is increased to 20 cm and flexural strength is improved. However, this increases labor costs, because the number of cross braces to be fitted is doubled.

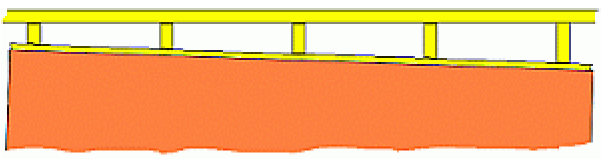


Options for use of different lumber sizes

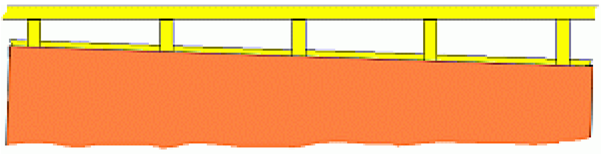


Use of different lumber sizes for transferring forces to the container side walls

The squared lumber should not be nailed to new container floors or those made from plywood and textured coated board. Instead, wooden members may be placed against the slab or fitted between the wooden bracing members. The methods which are generally possible are shown in the following diagrams.



Wooden members fitted against the slab for fixing the cross braces



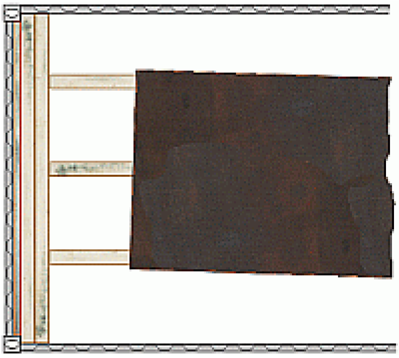
Wooden members fitted between the cross braces to fix the latter in place

The following is a real example using 14 cm x 14 cm wooden members.

securing on left-hand side **securing on right-hand side**

using 14 cm x 14 cm squared lumber

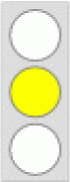
In the lengthwise direction, the container end walls can withstand uniformly distributed inertia forces amounting to 40% of the payload. If 20% friction is assumed, longitudinal forces of up to 60% of the cargo mass can be absorbed.

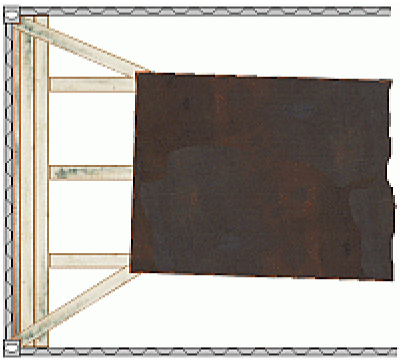


Bracing of the slab against the front end wall

There is no point in using more wooden members than shown as the front end wall would otherwise give way, being the weak point. The maximum securing load of the lengthwise wooden members must accordingly (almost) amount to 0.4 times the container payload.

If part of the transport operation is to take place in Europe by intermodal carriage by road or rail, stresses in the longitudinal direction of 80% to 100% of the slab's normal force must be expected. Given the assumed friction forces of 20%, 60% to 80% of the normal force must accordingly be applied as securing forces in the longitudinal direction. Since the front end wall cannot withstand such forces, bracing of 20% or 40% of the normal force must be provided against the container corner posts, in addition to the 40% against the front end wall.

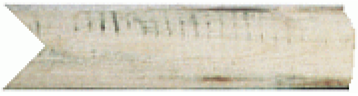




Bracing against corner posts with cut "birds' mouths"

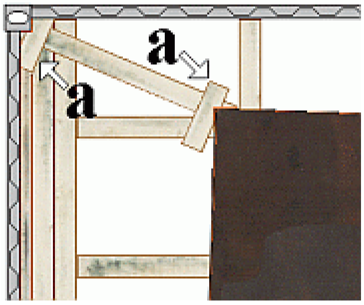
This is implemented with wedge-shaped cuts, or "birds' mouths", in the ends of the wooden members. However, this is only feasible if they are not cut at too acute an angle and the components against which they are to be braced are not too sharp-edged, as there is otherwise a risk that the members will split. Measures which can be taken to counter this problem will be explained below.

Favorable angle



Excessively acute angle

Since wood is relatively insensitive to notch effects at right-angles to the grain, one solution is to place additional wooden members between the oblique stays.

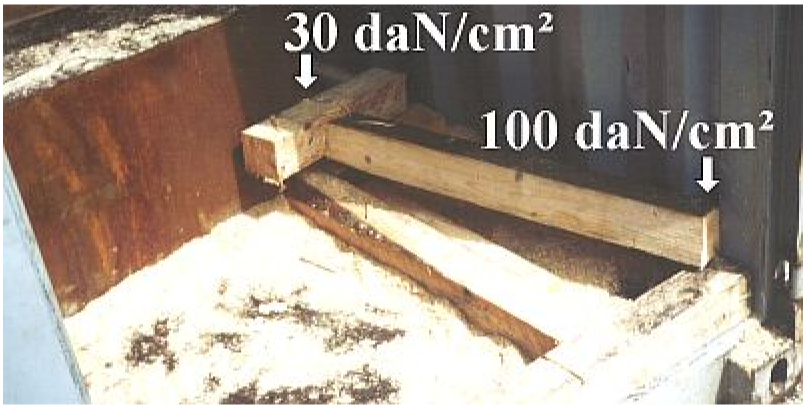


Oblique bracing using additional wooden members

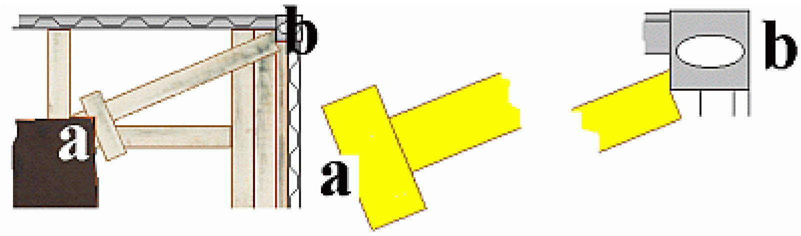
Notches are cut in the additional wooden members (a). The wooden members are placed against the corner posts and the corners of the slabs and the space between is braced with the oblique stays. Since these wooden members are loaded perpendicularly to the grain, for the purposes of calculation they can only be assumed to withstand loads of 30 daN per cm². Directly applied wooden members, which are loaded on the end grain, i.e. parallel to the grain, can be assumed for the purposes of calculation to withstand loads of 100 daN per square centimeter of cross-sectional area.

V-cut as notch in additional wooden member

Depending on the particular circumstances, the above variants may also be combined:



Different use of wooden members entails other calculations



Example of wooden members of varying effectiveness

At (a) on the slab, the V-cut provides an area of 10 cm x 10 cm for loading perpendicular to the grain. Loading capacity is accordingly 100 cm^2 ≈ 30 daN/cm = 3,000 daN. At the container corner posts, the wooden bracing member is loaded parallel to the grain. However, the forces act on only one third of the member. Loading capacity is 3.3 cm x 10 cm x 100 daN/cm^2 = 3,300 daN. This securing arrangement can be described as entirely homogeneous.

However, at the real angle of approx. 20°, approx. 94%, or 2,820 daN, of the securing is effective as a lengthwise component, as calculated from the cosine of 20°.

Left-hand end bracing

In the present real situation, the slab, once introduced, was braced first to the sides and then against the front end wall.

Additional transfer of forces to the corner posts

Subsequently, a squared lumber member was placed in the door area in such a manner that, with the doors closed, the forces are directly transferred onto the door leaves with lengthwise wooden members which are yet to be put in place. In addition, oblique stays were placed against the corner posts.

5.2.14.21 Slabs - vertical securing

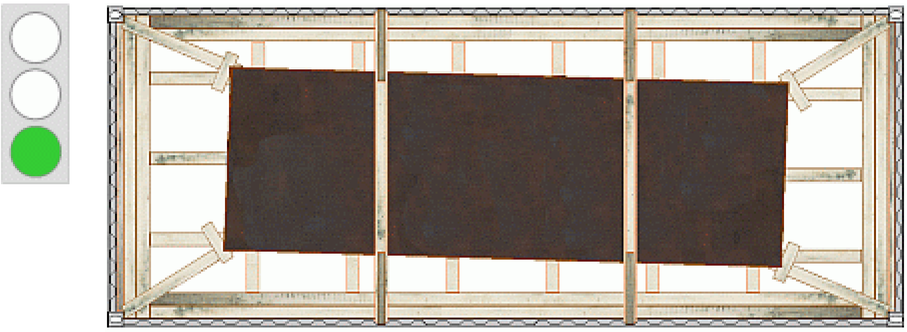
Vertical securing to counter shifting out of the floor-level securing

In order to prevent the slab from shifting out from the wooden securing members in rough seas or on exposure to other vertical impacts, shoring was arranged against the top side rails.

Fitting the final lengthwise bracing

Only after the left-hand door leaf had been shut were the outstanding lengthwise bracing members fitted between the slab and the crosspiece placed in front of the door.

In this way, the slab was well secured. Since mainly 14 cm x 14 cm squared lumber was used, this securing does not entirely correspond to the following diagram, which is based on the use of 10 cm x 10 cm wooden members.



Optimum securing of a slab in a box container

The essential difference between the actual situation and this diagram is that the diagram shows the doubled wooden members for distributing the pressure to the container walls in order to achieve a greater "depth".

It should be noted that the methods shown are virtually the only possible way to secure such heavy slabs in box containers. Securing by lashing is not possible. On the one hand for reasons of packing feasibility, because the slabs cannot be placed on supports, and on the other because conventional box containers only have lashing points with maximum securing loads of approx. 1,000 daN.

5.2.14.22 Slabs - load distribution in open-top containers

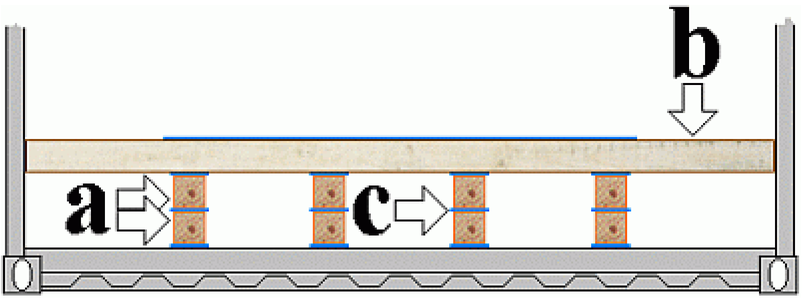
Packing slabs in open-top containers

The advantage over packing in standard box containers is that friction-enhancing material can be used. This substantially reduces securing effort in terms of the necessary maximum securing loads. Moreover, many open-top containers have lashing points with a maximum securing load of 2,000 daN. However, these values are lower than those encountered when loading on flatracks.

Supports are required so that the slabs can be set down during packing and lifted up again on unpacking, unless special slab tongs were used which would allow the slabs to be set down directly on the container floor.

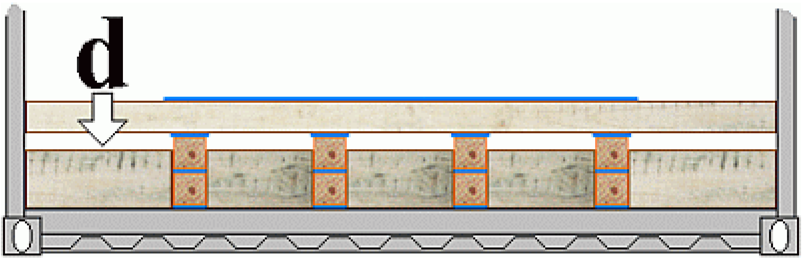
Bottom cross members of an open-top container

Lengthwise wooden members are required in order to distribute the mass of the cargo on the bottom cross members. Wooden crosspieces are necessary in order to be able to set down and lift up slabs using normal load suspension and slinging means. A lattice of wooden members must accordingly be laid before packing.

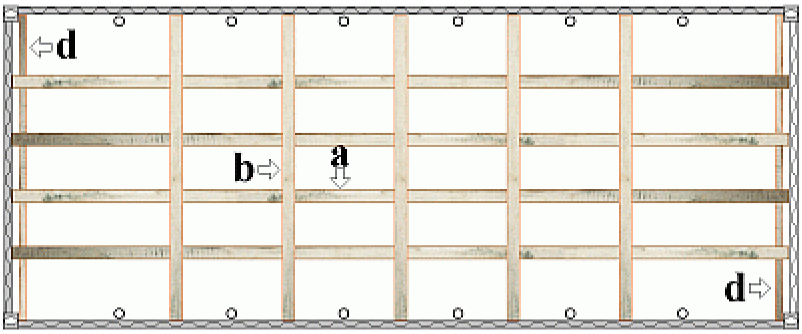


Cross-section of wooden lattice support for the slab

The stacked wooden beams (a) serve to transfer forces over the entire container floor, resulting in more effective transfer. Strips of friction-enhancing material are laid under, between and on top of the wooden members. The wooden crosspieces (b) are laid at right-angles across the lengthwise wooden members. Theoretically, they could finish at the outermost lengthwise wooden members. In this case, they are continued to the container side walls to ensure better stabilization of the overall securing arrangement. In order to prevent the stacked wooden members (a) from tipping, planks (d) are arranged vertically between them at the front and rear of the container).



Cross-section including lengths of plank (d) to prevent tipping



Lattice structure to transfer forces to container floor - plan view

A total of approx. 64 linear meters of squared lumber and planks are required for the lattice shown - a considerable expense.

5.2.14.23 Slabs - securing in open-top containers

In order to save time when crosswise securing is to be provided with loop lashings, single-use webbing belts or other equivalent lashing materials are laid out as shown in the following diagram:

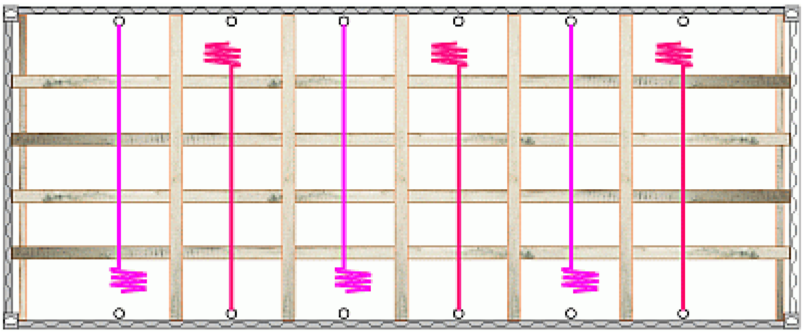
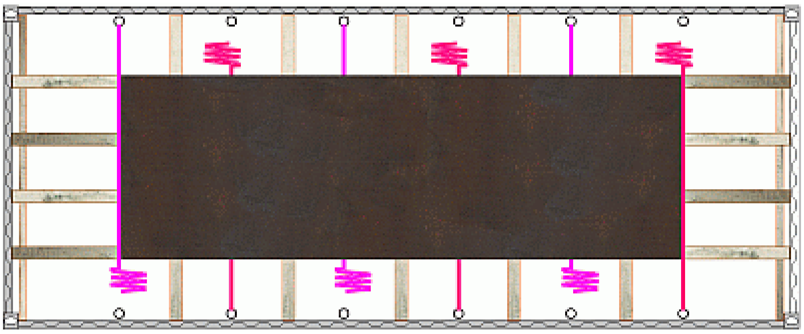


Diagram of layout of lashing belts - plan view

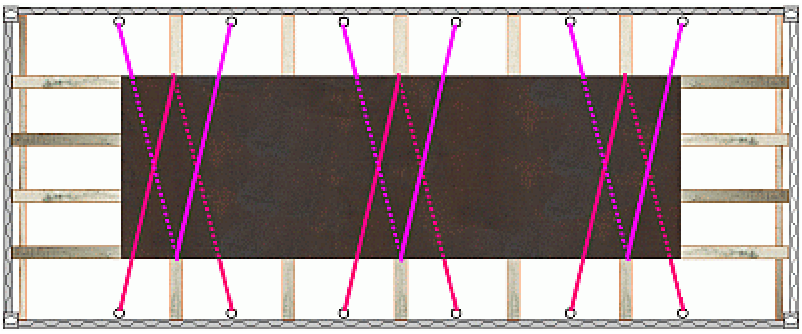
So as not to overload the diagram with details, the strips of friction-enhancing material which would also be laid are not shown.

After the preparatory work, the slab is set down ...

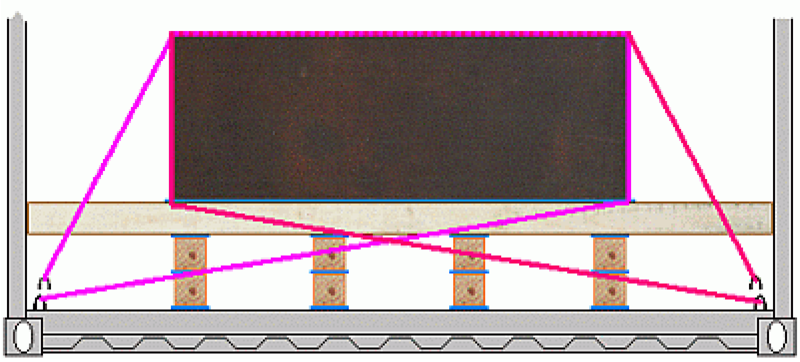


Slab set down on support - plan view

... and secured laterally with loop lashings.



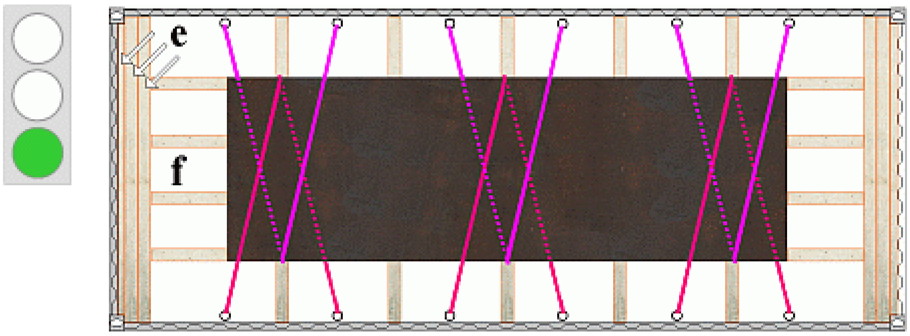
Slab with sideways tensioned lashings - plan view



Slabs with tensioned lashings - cross-section

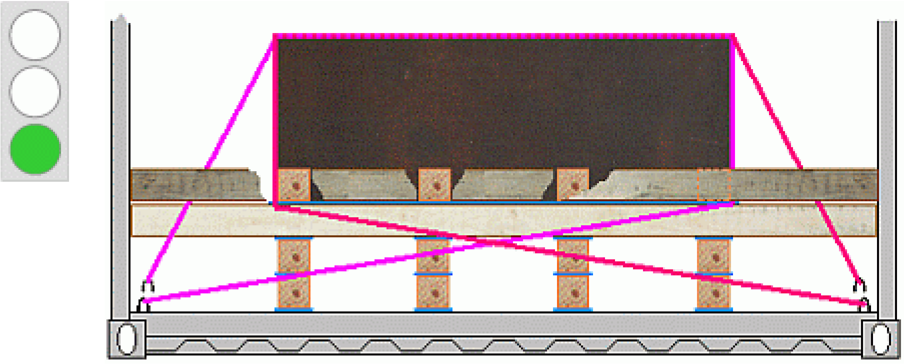
If webbing belts with a straight-line maximum securing load of approx. 2,500 daN are used, due to the horizontal and vertical lashing angle between the parts, they provide horizontal forces of 2,170 daN per run. This value is calculated from the maximum securing load of 2,500 daN multiplied by the cosine of half the angle between the parts in the vertical axis and multiplied by the cosine of half the angle between the parts in the horizontal axis. Since the lashing points can be subjected to loads of 2,000 daN in all directions and the ends of the loop lashings are attached to separate lashing points, the slab is tightly secured on each side with 6 x 2,000 daN = 12,000 daN. If the friction-enhancing materials are assumed to have a friction coefficient of μ = 0.4, friction forces of approx. 9,400 daN are obtained, while if a friction coefficient of μ = 0.6 is assumed, the friction forces could be as high as approx. 14,100 daN; In the latter case, just two loop lashings per side would then be sufficient.

The slab is braced to prevent lengthwise movement:



Lengthwise bracing of slab - plan view

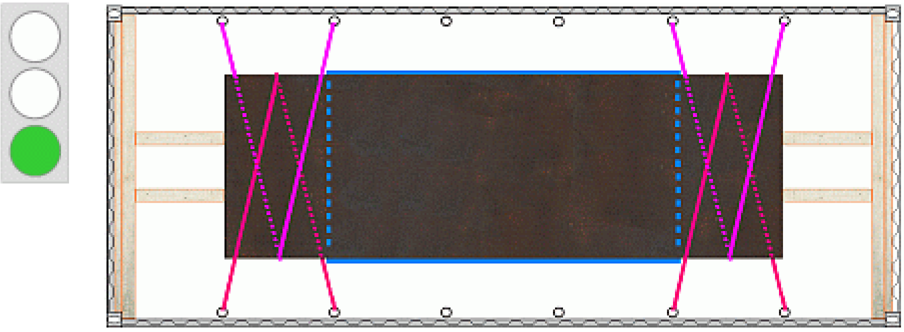
To this end, crosspieces (e) are placed against both end walls to distribute pressure and lengthwise wooden members (f) are inserted between these crosspieces and the slab and are nailed to the lattice members beneath.



Lengthwise bracing of slab - cross-section

The decision as to whether four lengthwise braces are inserted or whether two would be enough or whether smaller lumber could be used is taken on the basis of assumed loads and the estimated coefficient of sliding friction.

If lower mass slabs, which present no problems with regard to line load, are to be carried, the following securing method is very cost-effective with regard to both labor and use of materials.



Extremely cost-effective slab securing - plan view

Before the slab can be set down from above using webbing slings, an extensive area of the container floor in the area of the four central lashing points is covered with friction-enhancing material at least 10 mm in thickness and the slab is set down on this material so that the webbing slings can be removed from beneath the ends of the slab. (If the webbing slings are thicker than the material beneath the slab, a second layer of friction-enhancing material must be laid.) The single use textile lashing belts are slid beneath the ends of the slab, passed over the slab and tensioned. Lengthwise securing is provided by wooden bracing.

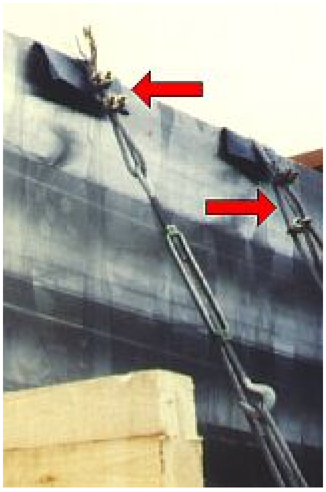
It should be noted in relation to any securing method using webbing belts that edge protectors must always be used with sharp-edged cargoes.

5.2.14.24 Slab-like steel parts on a flatrack

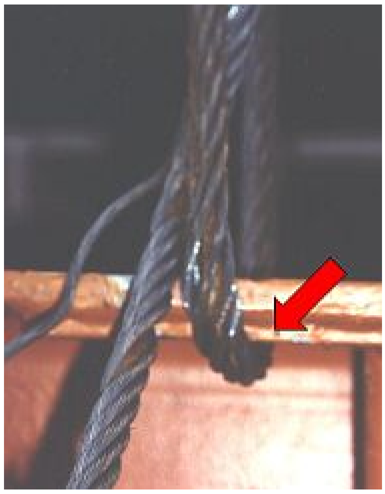
Inadequate cargo securing methods and poor workmanship mean that these slab-like parts are not sufficiently secured.

Inadequate securing

Only the lowermost part is secured in the lengthwise direction. The upper three parts can move freely in the lengthwise direction. None of the parts is secured in the sideways direction as sufficient securing forces cannot be applied even with several tie-down lashings.

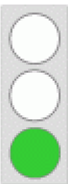


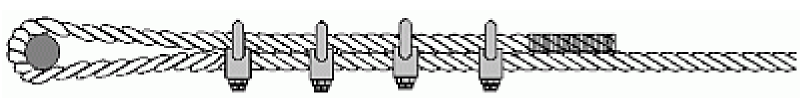
Incorrectly attached wire clips in insufficient quantity



Sharp edges weaken the wire rope

Too few wire clips have been used. Some of them have also be placed on the wrong side. Spacing between the clamps is inadequate. The tightening moment is too low.

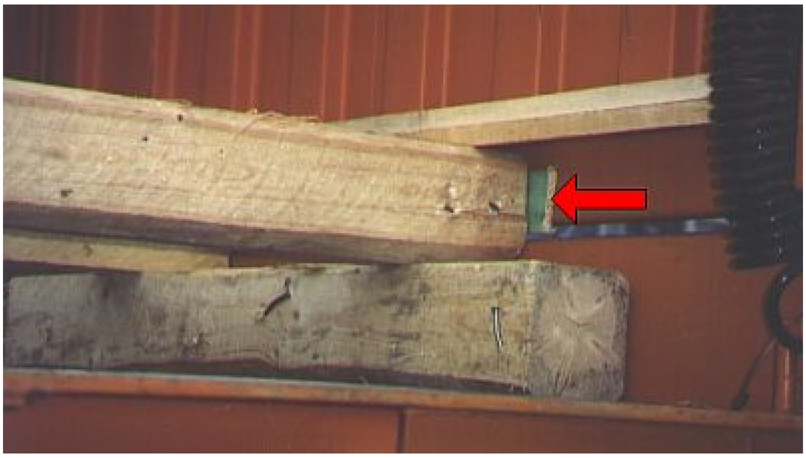




Only if four wire clips are correctly applied and properly tightened can the maximum securing load of the wire ropes and turnbuckles be fully utilized.

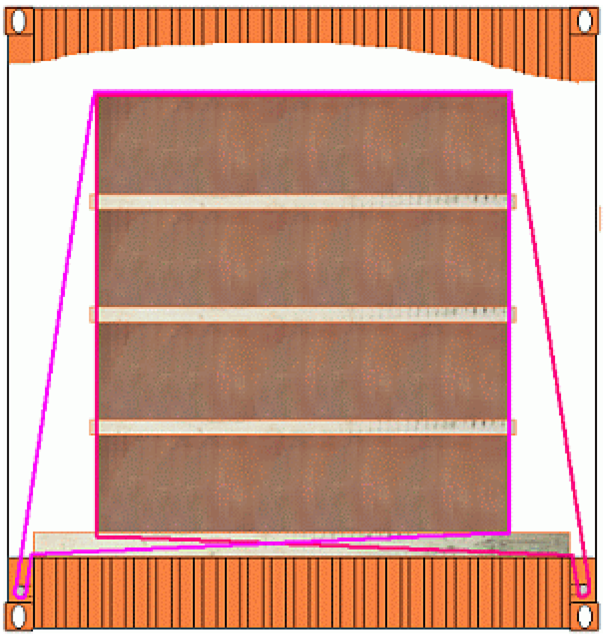
Inadequate effective height of wooden bracing members

Only approx. one quarter of the height of the squared lumber is actually effective, so that not only is little strength obtained, but much material is wasted too.



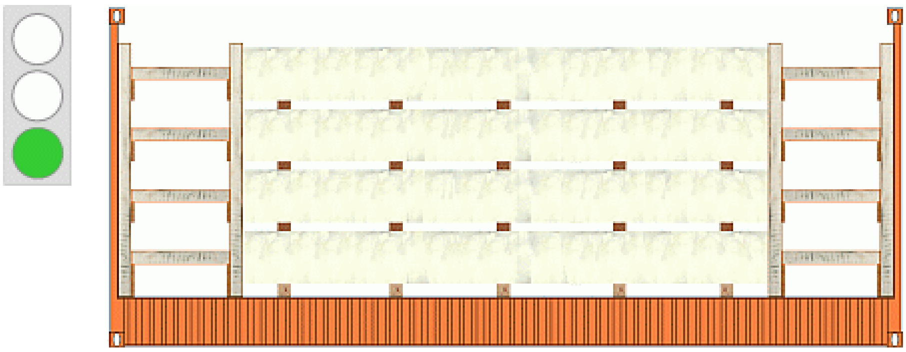
Effective cross-sectional area provided merely by small lengths of board.

Untidy workmanship has meant that short lengths of board have had to be inserted to fill the gaps in the squared lumber structure. The maximum securing load can be calculated from the contact area of the small board with the squared lumber and loading capacity perpendicular to the grain of 30 daN/cm². Without the board, the loading capacity would have been calculated in the case of a neat arrangement on the basis of the contact area of the squared lumber with the end wall of the flatrack with loading capacity parallel to the grain of 100 daN/cm², which would have produced a distinctly higher value.



Lateral securing using loop lashings
- cross-section

The parts could have been provided with lateral securing relatively simply by using loop lashings. Their number is determined by the anticipated shipping stresses, the lashing materials used and how they are applied together with any materials laid beneath or between the layers.

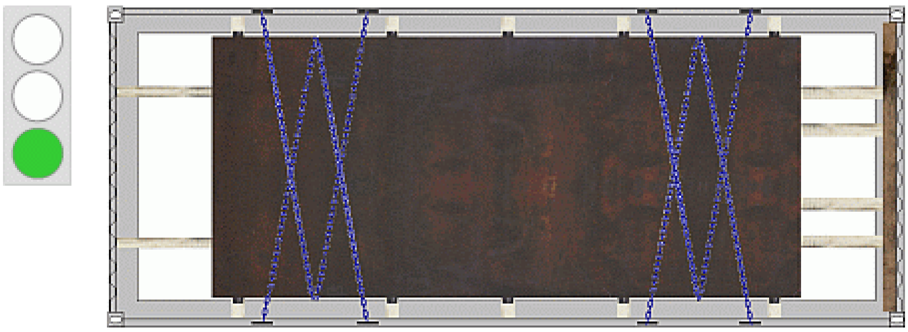


Lengthwise securing with wooden bracing - side view

In this case too, bracing with wooden members is an effective way of providing lengthwise securing. The loop lashings providing lateral securing have not been including in this drawing.

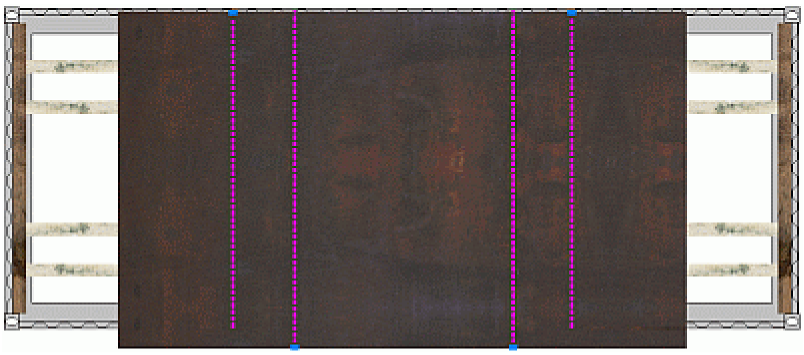
5.2.14.25 Heavy plate and sheet packages on flatracks

Heavy plate of a width less than the receptacles used can straightforwardly be secured on flatracks by wooden bracing and loop lashings. The crosspieces under the cargo should be laid in such a way firstly that they ensure adequate load transfer to the flatrack side rails and secondly that they do not obstruct placement of the necessary securing means. In order to minimize the securing forces which have to be applied, it is advisable to use "sandwich" supports, i.e. supports with strips of friction-enhancing material placed under and on top of the wooden members .



Heavy plate secured with loop lashings and wooden bracing

The nature of the flatrack's end walls determines whether it is possible to secure metal plates in the lengthwise direction only with wooden members loaded against the end grain (left) or whether wooden members loaded against the face grain have to be inserted to distribute the pressure (right). The different loading capacities of the wooden members can mean that different numbers of members have to be used.



Overwidth plate - loaded with overhang on one side and secured with claws

Slightly overwidth plates are loaded such that they overhang on only one side so that only two slot rates rather than three need be paid. Securing can be provided by claws fasted to belts, wire ropes, chains or the ends of the lashings on permanently installed reels. Since the lashing means have to be passed and fastened from under the cargo, it is advantageous to lay them out prior to loading, to apply the claws after loading and then to apply tension. Claws may also be replaced with suitably strong hooks with an adequate throat size.

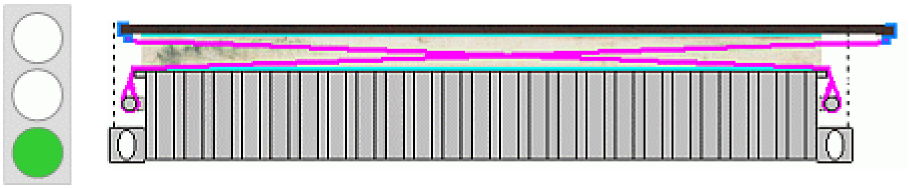
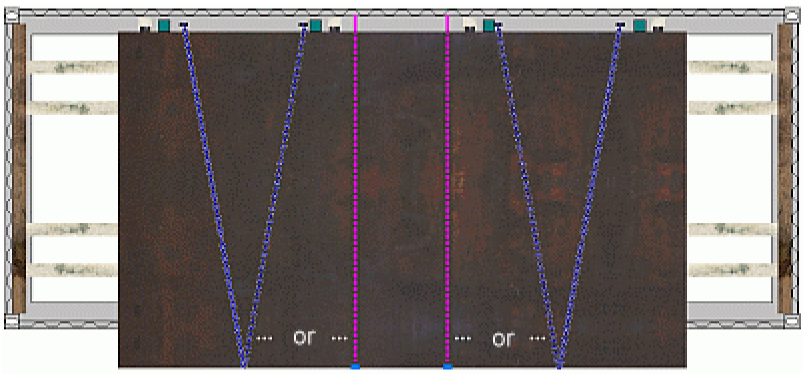


Plate overhanging on one side - secured with claws - cross-section

It is important for the lashings always to be applied from the opposite side. Otherwise, the angles are so unfavorable that sufficient lateral forces cannot be applied.

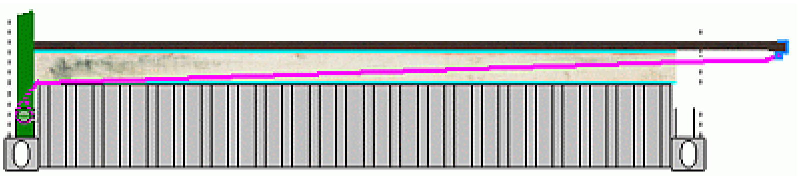
Unusable: tie-down lashings

Tie-down lashings must never be used to provide lateral securing as plates remain freely mobile under such lashings. However, such lashings can be used to provide vertical securing. In this case, they should then be viewed as direct lashings preventing upwards movement and so require only slight pretensioning. Such securing methods can ideally complement lateral securing with claws.



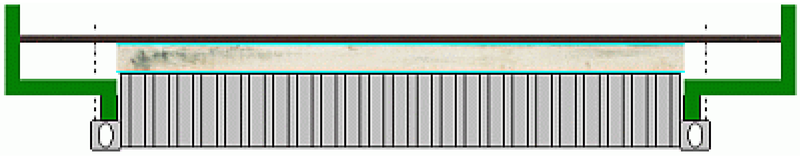
Overwidth plate - loaded with overhang on one side and secured with stanchions and loop lashings applied on one side

Using flatracks with stanchions simplifies securing. In this case, the plates are laid with one side against the stanchions, while movement towards the other side is prevented with loop lashings or lashings fitted with claws.



Overwidth plate - loaded with overhang on one side and secured with stanchions and direct lashings with claws applied on one side - cross section

Overwidth plate - loaded with overhang on one side. Secured with stanchions and specially shaped stanchions applied on one side - cross-section

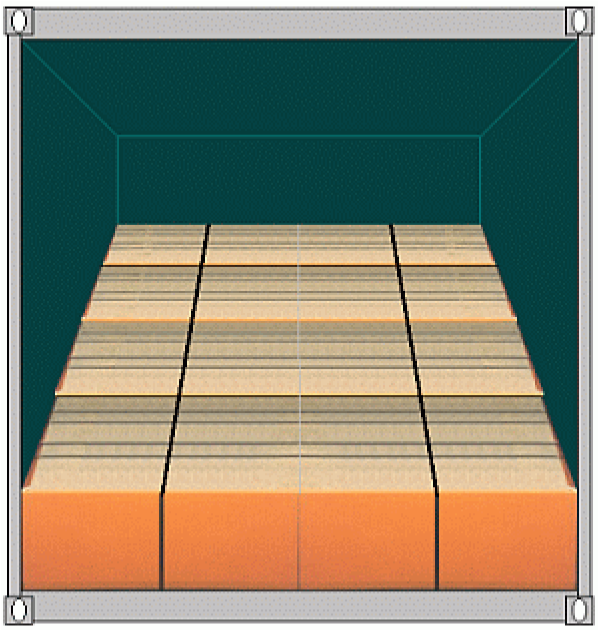


Overwidth plate - loaded with overhang on both sides - secured with specially shaped stanchions - cross section

Depending upon the plate sizes to be transported, it may be advisable to use specially shaped stanchions. If these are not an exact fit, relatively small gaps can be filled in with lumber. The securing action of stanchions or specially shaped stanchions should be complemented by direct overlashings. As already mentioned, such lashings are applied in the same way as tie-down lashings, but they are not tie-down lashings as they do not act in the same way.

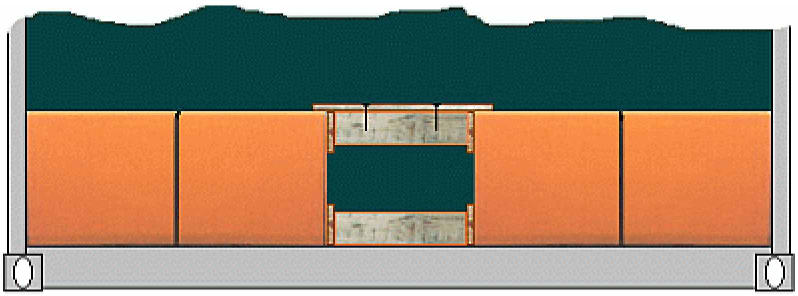
5.2.14.26 Sheet packages in box containers

Sheet packages



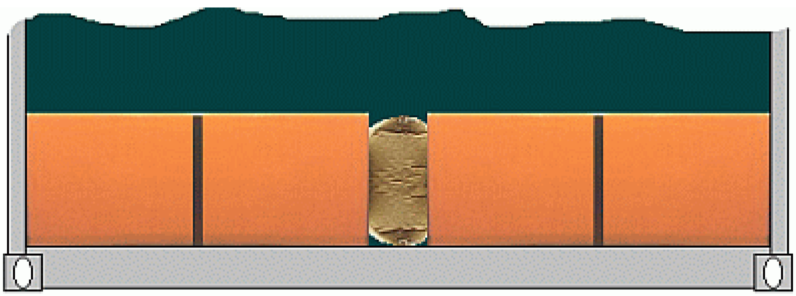
Box container compactly packed with sheet packages

It is ideal if the sheet packages to be packed are tailored to container dimensions as transport modules in such a manner that compact packing is possible.



"Aisle" braced with boards and squared lumber

Since this not usually the case, the packages should be packed flush against the container side walls and the "aisle" remaining in the middle should be braced with squared lumber and boards.



"Aisle" filled with airbags

If the aisle is around 20 cm wide, airbags can certainly be considered for filling the gap. It must, however, be ensured that jolting in transit cannot cause the airbags to shift upwards.

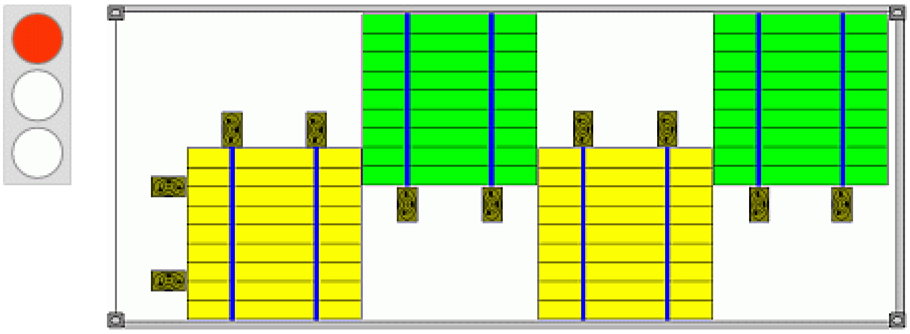
Stainless steel sheet in unitized wooden cases

Carefully thought out stowage patterns are a fundamental prerequisite for reasonable load securing and help to minimize labor and material costs. Good stowage planning also ensures that subsequently discovered securing shortcomings can be corrected more quickly and cheaply.

Unfavorable stowage pattern and inadequate securing

In this case, stainless steel sheet in wooden cases is being stowed, groups of ten cases being unitized with steel strapping to form a cargo unit. Neither the stowage plan nor the securing is adequate. Since each unit has a mass of

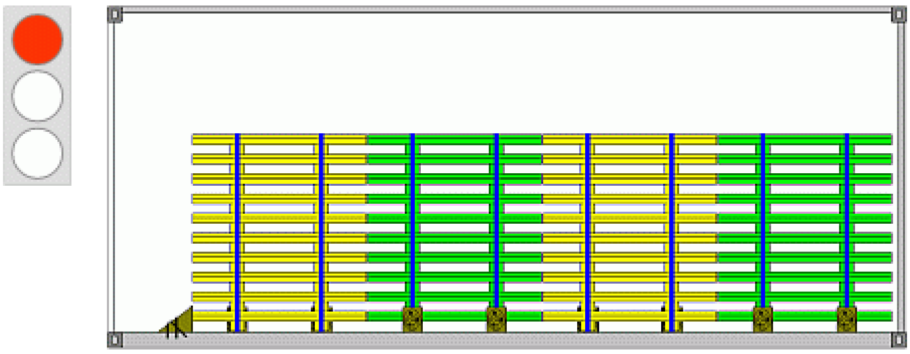
approx. 4 metric tons, securing with wedges is not possible and is thus completely inappropriate.



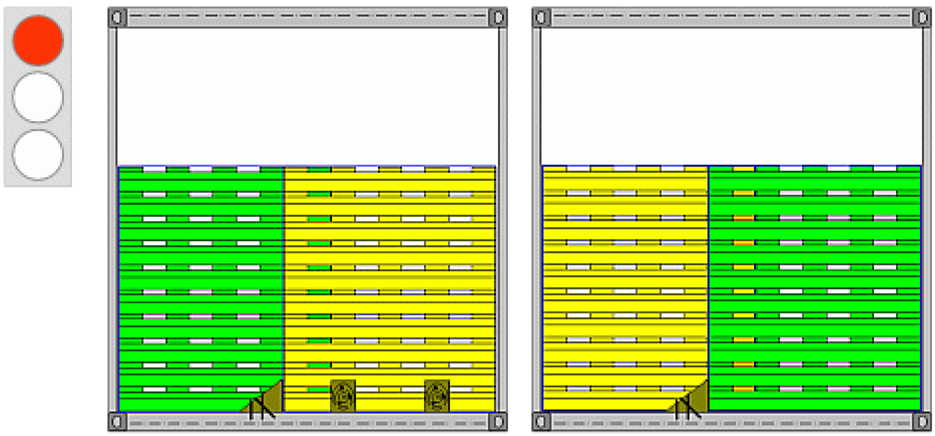
Stowage pattern and inadequate securing - plan view

The plan view shows the overall packing method. Each cargo unit is "secured" laterally with 2 incorrectly cut wedges, each of which is fastened to the container floor with one tension nail and two retaining nails. Assuming normal shear strengths, the units are "secured" with a force of approx. 400 daN, instead of the necessary 3,200 daN.

No action has been taken to counter the tipping forces which occur in maritime transport. All four units, with a total mass of approx. 16 metric tons, are also "secured" in the lengthwise direction with only two wedges which may likewise be expected to provide a securing force of only approx. 400 daN, instead of the 6,400 daN required to withstand the acceleration forces anticipated in maritime transport and the 12,800 daN in road transport.



Stowage pattern and inadequate securing - side view

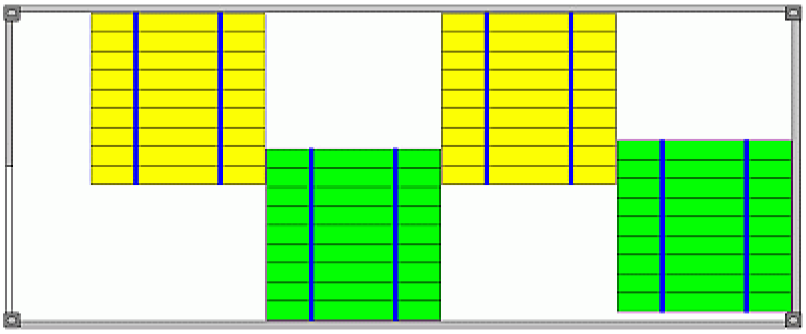


View from the door **View from the front end**

Due to inadequate stowage planning, it is difficult to remedy the securing deficiencies. Since the final unit is in the door area, sensible securing methods cannot be used. The result, as in the following similar case, is an unsatisfactory improvised stop gap.

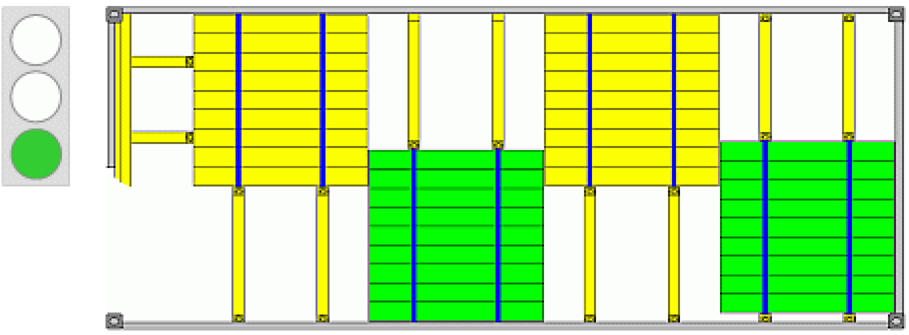
Improvised securing against a corner post and the left-hand door leaf

Just using a different packing method could have created ideal conditions for reasonable securing.



Advantageous packing method facilitates subsequent securing.

This packing method would mean that the final cargo unit would be located in the vicinity of the left-hand door leaf, so allowing it to be closed and act as an abutment for horizontally placed bracing.

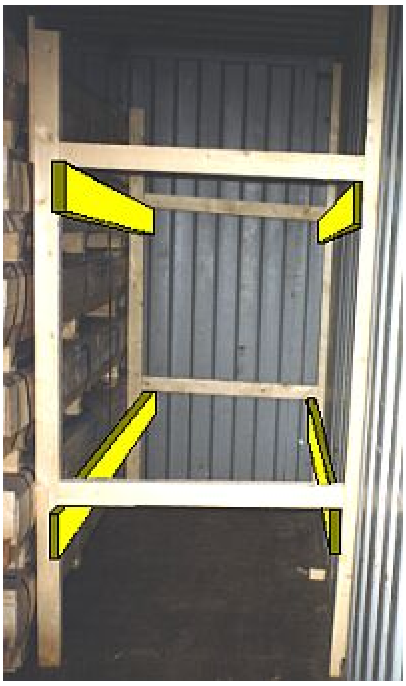


Securing by horizontal bracing with wooden beams

Once packed, each package is braced against the container walls. The final cargo unit is additionally braced against the left-hand door leaf.

In detail, the securing arrangements could look as follows:

Lateral securing with vertical uprights and transverse squared lumber beams



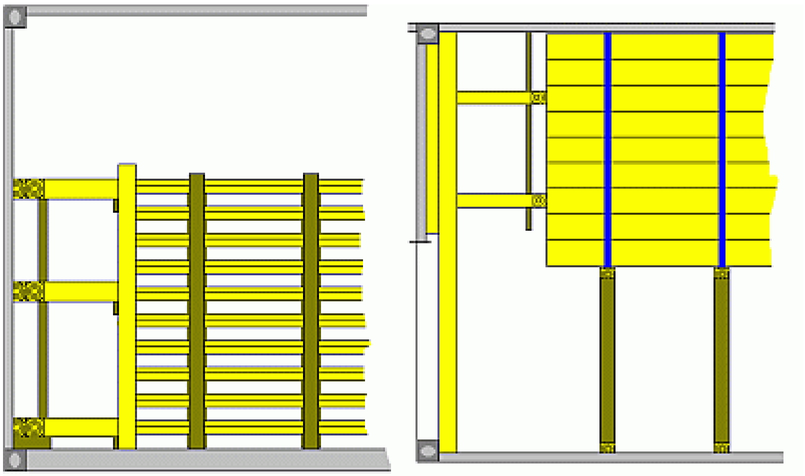
Securing as before, but joined together with boards

Sufficient lateral securing can be provided by inserting 6 cm x 8 cm wooden bracing members. The left-hand variant may be considered adequate if

- the upright members are firmly located between the container corrugations,
- the upright members can be nailed into place on the cargo and
- the horizontal wooden bracing members can be securely fasted onto the upright members.

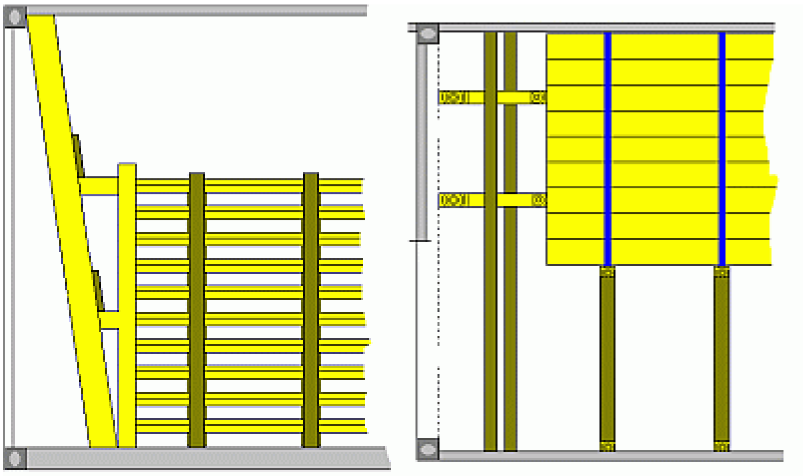
If the bracing is not durably fixed in place as in the left-hand Figure, additional lengthwise board connectors should be provided as in the right-hand Figure.

Various methods are feasible for final securing in the door area:



Horizontal bracing in the door area
- side view and plan view

Bracing applied horizontally against the door leaf is only advisable if the residual forces to be absorbed are not excessively large. This will be the case if friction-enhancing material has been laid beneath the cargo units so that relatively high friction forces already apply.



If there is a risk that transferring the forces to the door leaf could result in overloading, one solution is to use "shoring", which transfers the forces into the door header and the container floor.

5.2.14.27 Ingots in box containers

Ingots

Ingots are blocks of metal which are cast into a particular shape. They can vary greatly from metal to metal and from production site to production site. Aluminum, lead, zinc and tin are very often transported in this form.

Loosely stacked tin ingots in storage

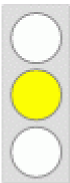
Individual bars are very often stacked at right angles to one another and bundled for transport.

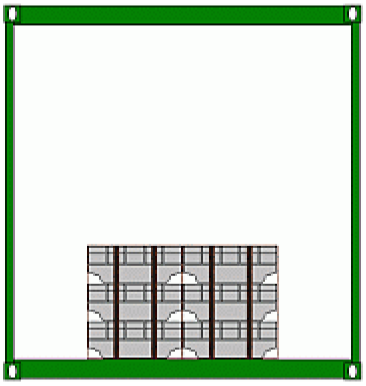
Lead ingots in a 20' foot box container

It may be suspected that this cargo was stowed on the basis of the age-old argument, "This cargo's so heavy, it will never slip!". However, it takes more than constant repetition of such erroneous ideas to overcome the laws of physics.

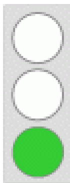
"Securing" with lengths of board nailed in front

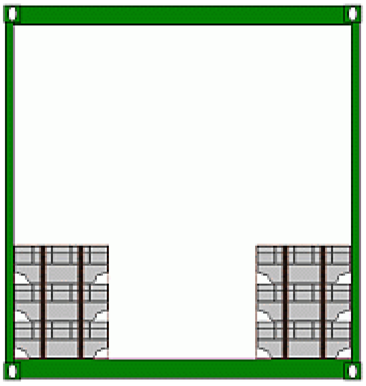
Packing of this 20' container has been carried out with complete disregard for all the basic rules of stowage. The large gaps in the stow and the considerable mass of the ingots are capable of jeopardizing the container and the means of transport.





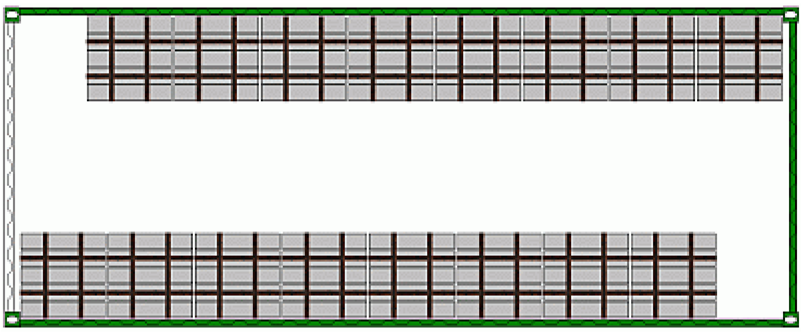
Centrally packed ingots





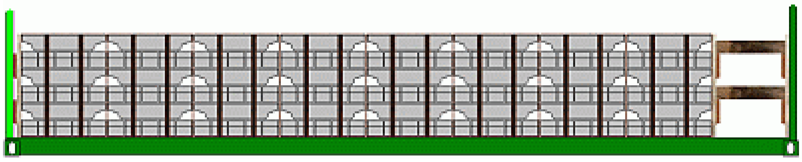
Laterally packed ingots

It is not incorrect, just uneconomic, to pack ingots centrally, as considerably more effort is required to secure them than if they are packed against the sides of the container. If the gap in the stow is left in the center of the container, more than half the cargo securing material can be saved.

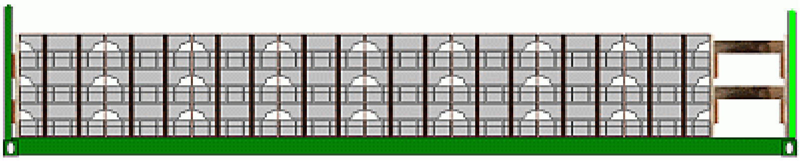


Laterally packed ingots - plan view

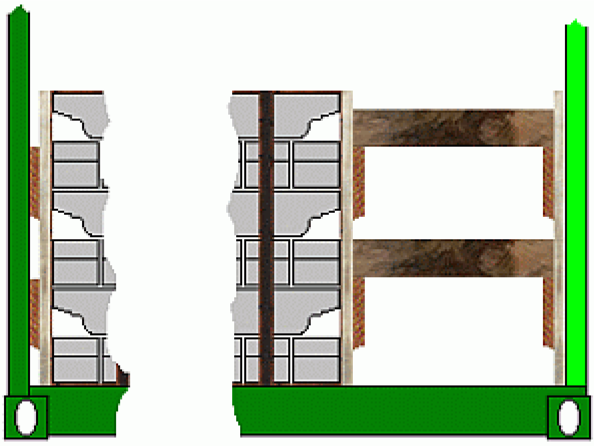
Ideally, transport modules should correspond to fractions of the internal container dimensions, but that is not the case here. The cargo has thus been packed so that bracing can be provided behind the first door leaf to be closed. On the side of the door leaf to be closed last, the cargo is packed in such a way that it can be blocked at the end face.



Side view of right-hand row of ingots bundles - door light green

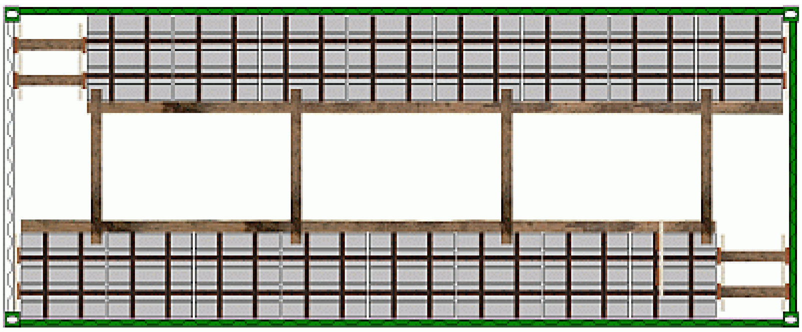


Side view of left-hand row of ingot bundles - door light green



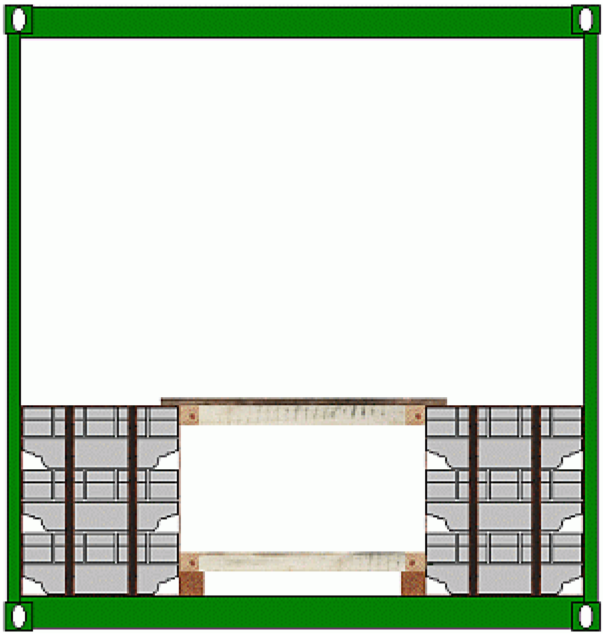
Detail of lengthwise securing

If narrow lengthwise gaps remain on the right-hand door side, they are filled with a lattice of two boards nailed to one another crosswise. The large lengthwise gaps are braced. Bracing is provided by two of the above-described lattices, between which two squared lumber members are fitted at top and bottom.



Bracing of transverse gaps - plan view

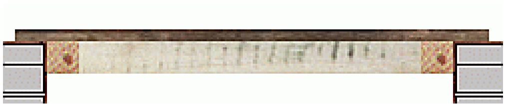
The large transverse gaps are braced with squared lumber members fitted lengthwise and crosswise as shown in the diagram.



Bracing of transverse gaps - cross-section

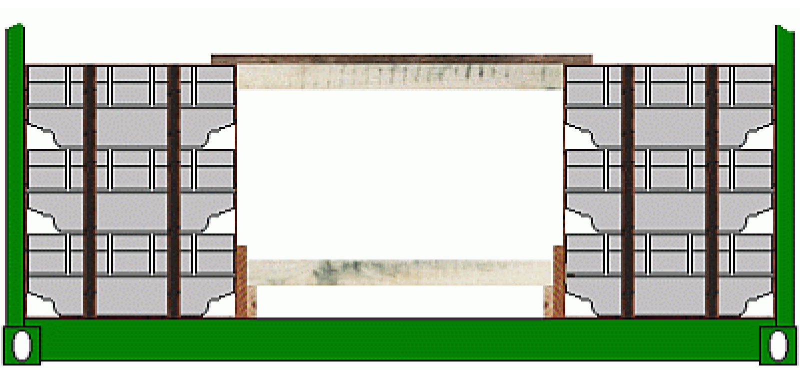
**Bracing of transverse gaps
- detail of lower part**

The bracing can be produced very quickly by laying a squared lumber member along the entire length of the lower edge of the internal sides of the bundles. A second squared lumber member of a smaller edge length is placed on top and the space between is braced in the crosswise direction with squared lumber members or beams which are cut to size.



**Bracing of transverse gaps
- detail of upper part**

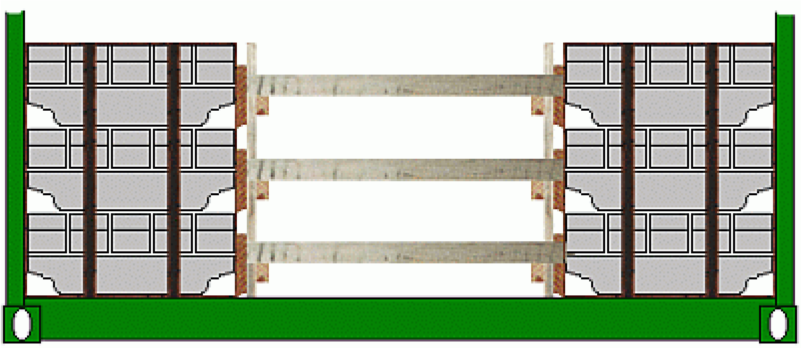
The bracing for the upper part can be prefabricated outside the container. Two squared lumber members are laid out lengthwise in accordance with the bundle position. The space between is filled with transverse squared lumber members. Boards, which overhang slightly on each side, are nailed onto the crosswise and lengthwise wooden members. The whole structure is suspended in the gap.



Bracing of transverse gaps - simpler variant

If the ingots are well bundled, crosswise bracing consisting in the lower part of boards nailed together in steps and crosswise wooden beams is sufficient. In the upper part, one bracing structure consisting of a wooden beam and a

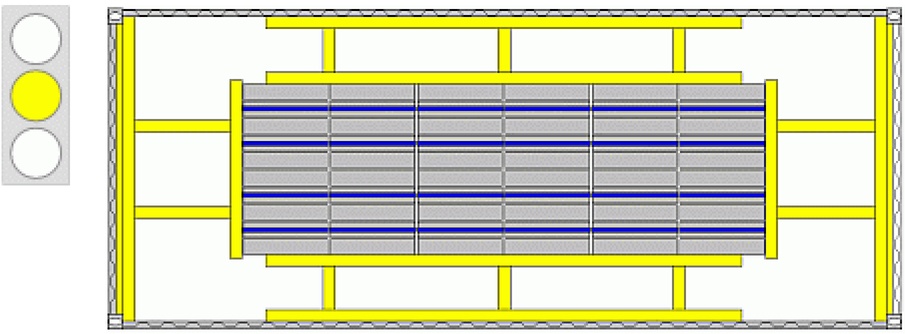
board nailed to it is suspended for each package.



Bracing of transverse gaps - complicated variant

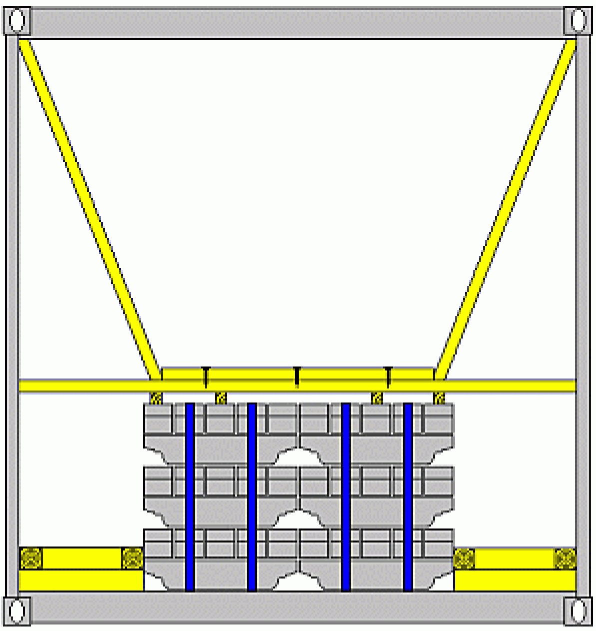
With poorly bundled ingots, where there is a risk that individual metal bars could come out of the bundle, bracing must be provided which retains every bar with a wooden member.

In all the bracing structures shown, the crosspieces must be secured against shifting by obliquely placed boards or "X-bracing". The dimensions of the lumber should be determined as a function of the masses to be secured and the necessary residual securing forces according to the rules of thumb stated in the general section.



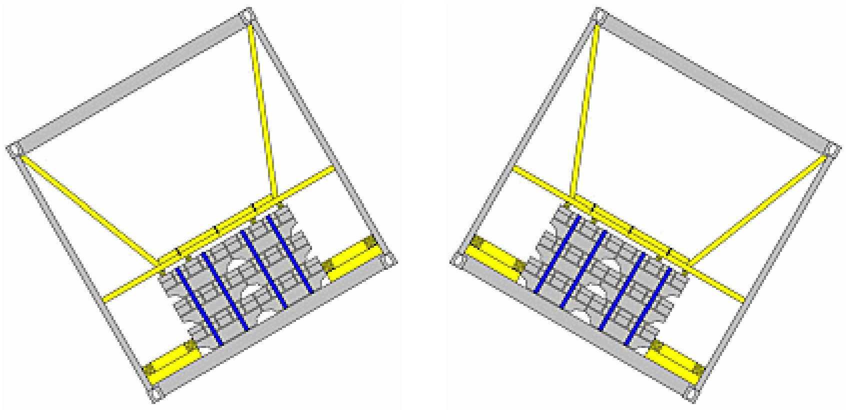
Bracing of a centrally placed cargo block - plan view

Stowing a complete block of bundles centrally entails higher material and labor costs. In order to keep such costs within acceptable limits, securing is only provided at floor level in the example.

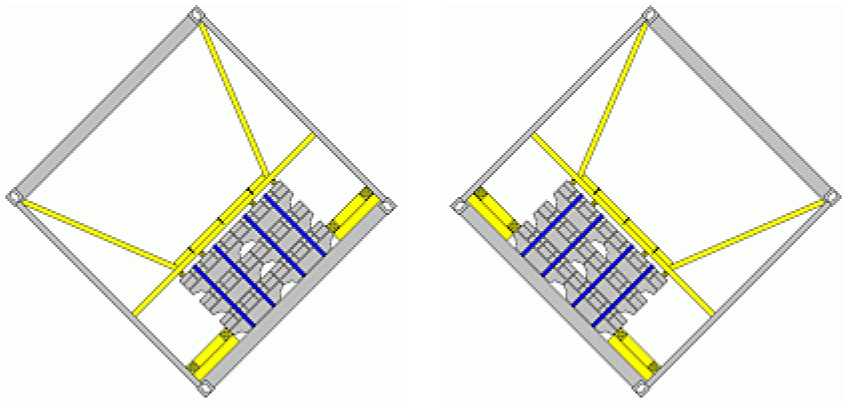


Securing a cargo block against tipping and vertically - cross-section

The block can be secured against tipping and vertical stresses by shoring. Lateral securing within the individual layers of cargo is provided by friction due to the pressure exerted by the shoring.



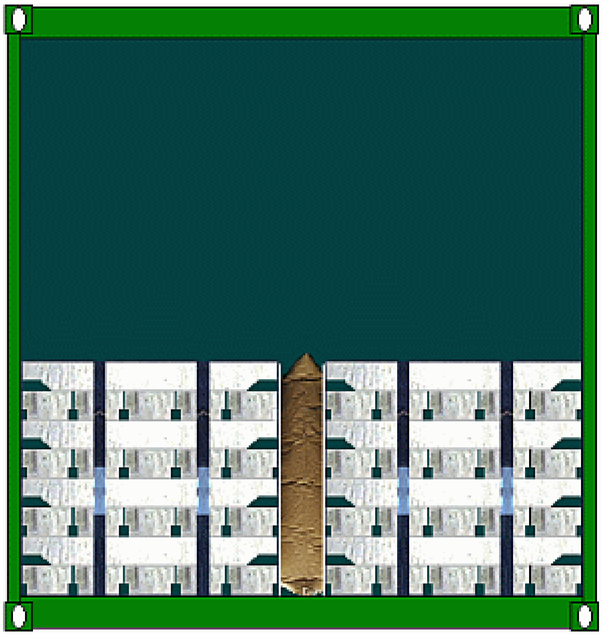
30° tilt of cargo block



45° tilt of cargo block

A properly secured cargo must also be able to withstand a rolling angle of 30° or 45° on board ship.

In terms of labor and material costs, airbags are hard to beat pricewise, but the gaps to be filled in the stow must only be narrow.



Aluminum ingots - secured with airbags

The aisle left between these aluminum ingots is so narrow that using airbags is feasible. Hardboard or thin sheets of plywood should be placed between the ingots and the airbags. Any airbags used must be secured against slipping out.

5.3 Primarily heterogeneous general cargoes

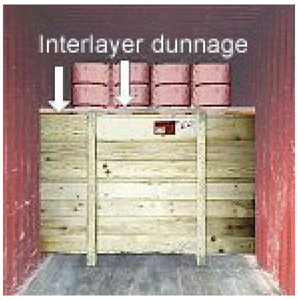
5.3.1 Bales/rolls

5.3.1.1 Bales, mixed cargo

In principle, bales tend to be loaded in unitized batches, whether they consist of natural rubber or latex, raw wool, raw cotton, combed top or the like. Occasionally, however, individual bales may be packed into an LCL container. Since most bales are only stable in large blocks but, apart perhaps from tobacco bales, are relatively insensitive to pressure, it is feasible to stow the bales in amongst other cargo. A hypothetical example is given below.



Because the bales are brought into their packing position using a forklift truck with bale clamp, they were packed with their narrow, curved side in the direction of the longitudinal axis. Floor dunnage was omitted, but wooden interlayer dunnage was put in place. If the ends are virtually flat, interlayer dunnage is unnecessary. Floor dunnage would be necessary, if the ends of the bales were not packaged and there was a risk of soiling.

For reasons of weight distribution, a batch of bales was stowed in this example with one case and two copper wire reels. Wooden interlayer dunnage was placed on the case, because the middle members of the pallet would otherwise have rested solely on the belt battens of the case. If the pallets were capable of remaining secure without interlayer dunnage, the latter could have been omitted.

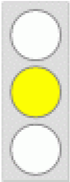
Another batch of cotton bales was placed in front of these stowed items and cases and cartons were packed in front of them. If there are no special reasons, such as weight distribution, why all the bales to be packed should not be stowed in one block, it is preferable to do just that, so that the forklift truck with bale clamp does not have to wait around unnecessarily or so that the forklift truck, if only one is available, does not have to be changed over repeatedly from clamp to fork tines and vice versa.

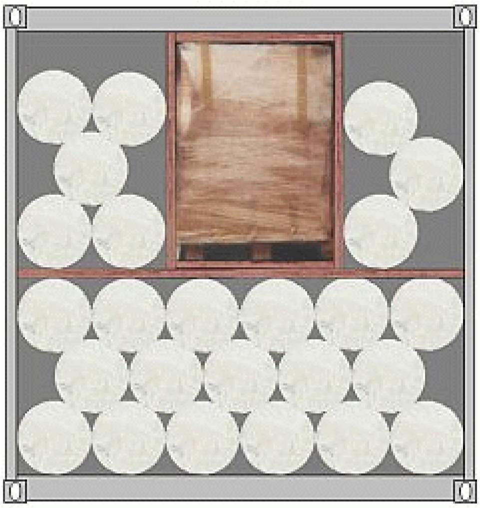
5.3.1.2 Rolls

Inadequate packing of textile rolls and a pallet

It is unlikely that the textile rolls will be capable of standing the stowage method illustrated.

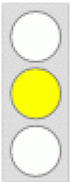
There are many ways of packing such cargoes appropriately into a container. Depending on the type of material in the rolls and how tightly they are wound, the layers are more or less firm when packed in the cantline. The following drawings all bear an amber light, because additional measures need to be taken which are not shown here.





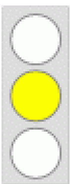
Packing variant sample

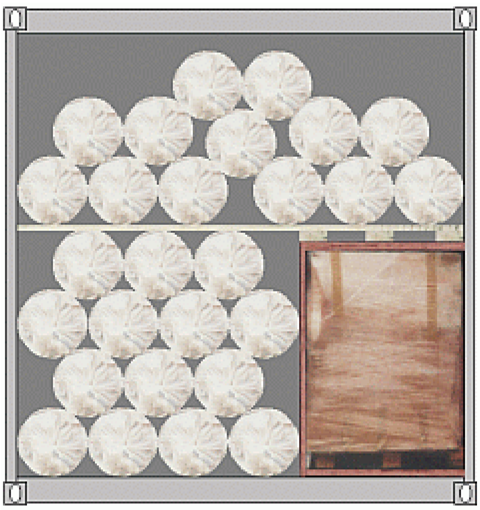
Wooden dunnage consisting of walking boards has been laid on the lower layers, and the pallet loaded centrally on that. The pressure-sensitive sides of the pallet have been protected with lateral dunnage of equivalent material, which provides protection in the form of boards or the like against excessive pressure in the upper area of the pallet.



Packing variant sample

Here, the pallet was protected against harmful pressures by lateral and top dunnage. The textile rolls were all packed in the cantline.





Packing variant sample

As before, the pallet in the picture above was protected against harmful pressures. Some of the textile rolls were packed somewhat higher than the pallet in the cantline. Walking boards, similar flat materials or boards were used

to provide a uniform packing support for the remaining rolls, so meaning that firring in the form of pieces of lumber had to be fitted in the area of the pallet. The upper rolls were also packed in the cantline.

The following pictures show that consideration must be given to securing the upper rolls by tying them together or similar measures. At tilt angles of up to 30° or acceleration of up to 0.5 g, the rolls would probably still remain in place, but this becomes highly questionable at larger tilt angles or greater acceleration.

Tilts of 30° correspond to 0.5 g acceleration

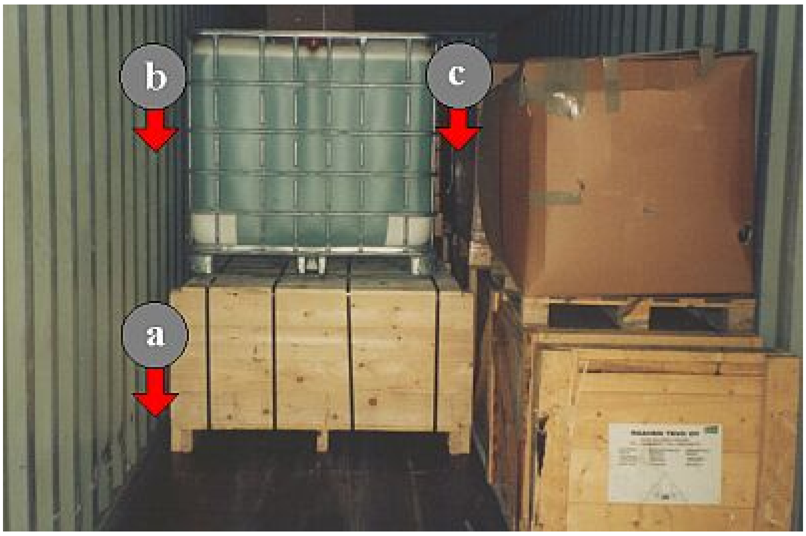
Tilts of 45° correspond to 0.7 g acceleration

In addition to bundling, it is also particularly expedient to use relatively softly inflated airbags at the sides to the left and right, to fix the rolls in their packing position.

In general, however, the question arises whether textile rolls are really strong enough to be packed in so many layers at all. Intensive thought should be given to other stowage methods. The producer's specialist knowledge of the product should definitely be utilized.

5.3.2 Receptacles, small and IBC

The gaps (a), (b) and (c) are unacceptable.

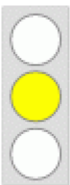


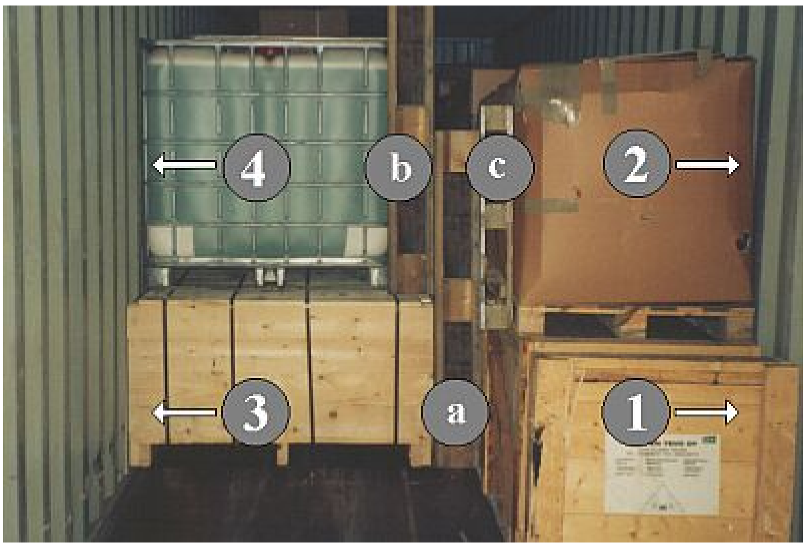
Gaps in a box container

The deficiencies become clearer when the container is tilted 30° about its longitudinal axis.

This tilt corresponds to lateral acceleration of 0.5 g, as has to be taken into account in road and rail transport too.

The bare minimum required to eliminate these deficiencies is packing the packages (1), (2) and (3) and (4) tightly against the container side walls and filling the gaps then remaining in the middle with the pallets (a), (b) and (c).





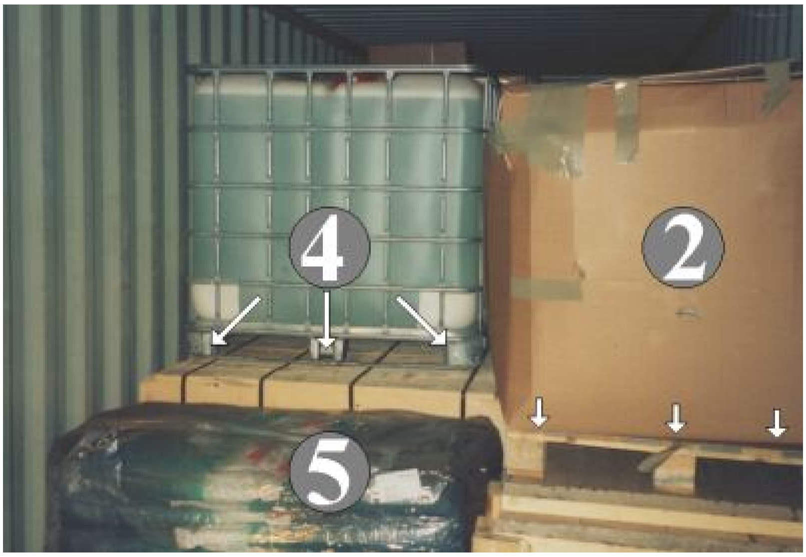
Improvements to a packed container section

For maritime transport, the container section must not be left like this, since inertia forces stemming from the IBC (4) are transferred in part via the pallets to the package (2) and may compress and damage the latter. This may create enough space for the container contents to "self-destruct".

Bracing against a container side wall

Thus, if pallets are used to improve packing, they must be prevented from making any movement, which may be achieved with two squared lumber members (d) fitted crosswise. The compressive forces they may cause should be distributed to part of the container side wall using a board (e). The squared lumber should be secured from below against sliding down by squared lumber or board ends (f). In some cases, attachment to the pallet may suffice.

The packing inadequacies are clearly visible in this picture too:



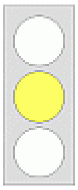
The carton (2) is obviously too weak and is standing loosely on the pallet-like base.

Intermediate Bulk Containers (IBC) (4) generally have very small contact areas and can only be stowed without using dunnage on container floors or stable set-down surfaces, such as the wooden case shown here.

Individual bagged cargo pallets (5) should where possible to packed into the upper layers, since overstowing them with other cargo requires the use of interlayer dunnage.

5.3.3 Barrel cargoes, mixed cargo

5.3.3.1 Mixed cargo with barrels, example 1



Mixed cargo in a 20' box container

The cable reel at the front of the container is immediately obvious. It should be noted that this is not fully wound, so meaning that there are no problems with weight distribution in the container.

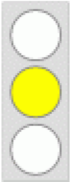
The securing of cable reels is covered in the special section relating to cable reels. Here, a critical eye will be cast over the packing and securing in the container door area.

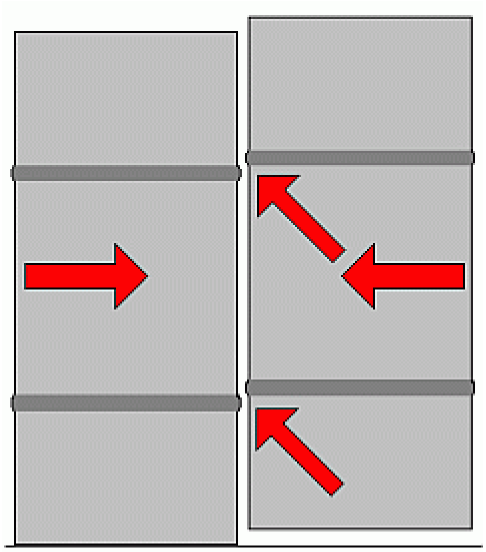
Cargo risks in the door area

If one looks closely, it is clear that any tilting of the container to the left could cause damage to the corners of the cartons on the pallet, if the forces exerted by the barrels press via the vertically positioned sheet package onto the corners of the cartons.

It may be noted that the right-hand barrel has been raised, with the intention of preventing the barrels from being pushed up by the corrugations. The idea is a good one, but is only feasible with two barrels stowed as a pair.

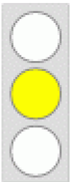
A better understanding will be gained from the following comments.



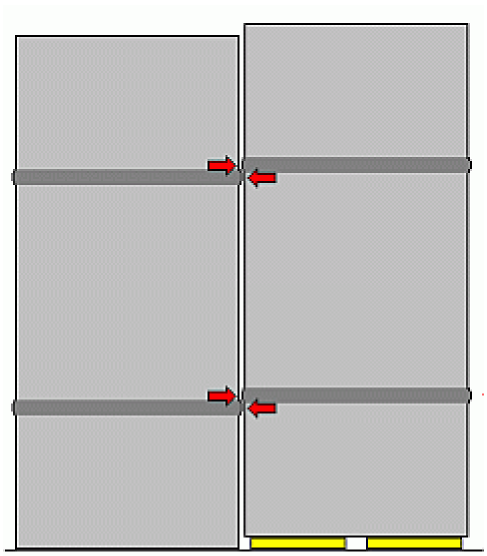


Barrels worked upwards by their corrugations

Conventional corrugated barrels have the unfortunate habit of pushing one another upwards by the corrugations and "hanging" from them. This disadvantageous design may thus lead directly to damage. Moreover, this pushing-up effect creates gaps in the cargo, which indirectly cause destruction of the drum due to the inertia forces which additionally arise.

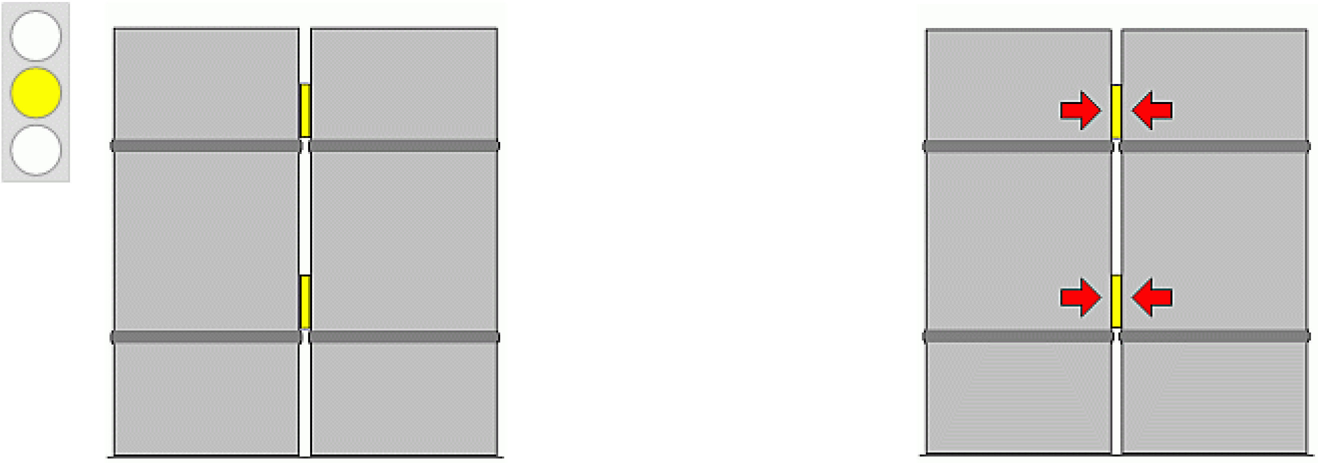


Alternate raising of barrels using boards



Although barrels can be alternately raised using stowage supports, this method can only be applied to barrels stowed in pairs. In a block consisting of more than 2 barrels, the method is no longer usable, as well as being material- and labor-intensive. Moreover, damage may arise, since the loading capacity of the body of a barrel is less than that of the corrugations, so meaning that, under elevated forces, the corrugations may form dents in the barrel bodies.

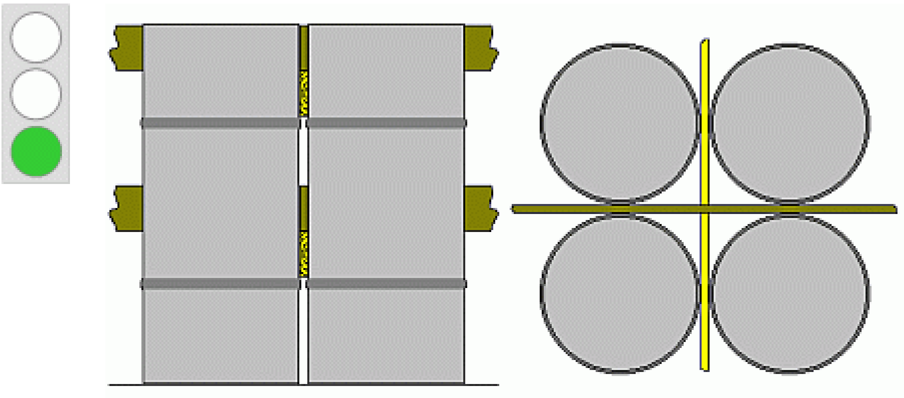
A possible way round the problem is to fill the gaps between the barrels with boards or the like.



Filling of gaps created by barrel corrugations

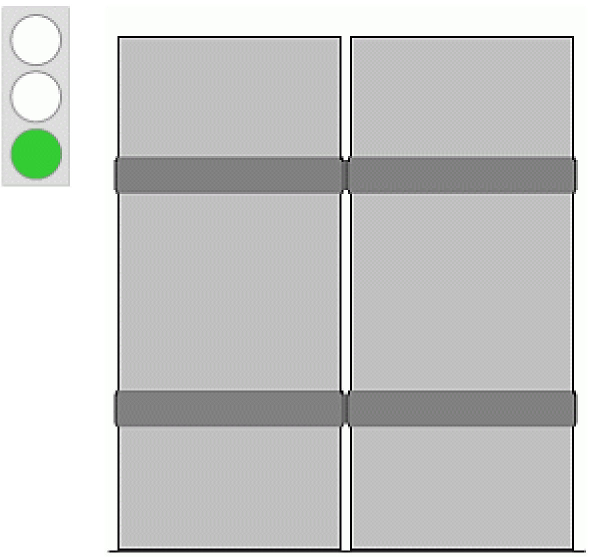
A note of caution must be sounded, however: if bearing areas are too small, excessive pressure may still cause denting of the barrel bodies.

The use of load securing foam would help avoid high pressures. However, such foams can only be used for rail and road container transport and are prohibited for maritime transport because their recovery is too low.



Filling of lengthwise and crosswise gaps created by barrel corrugations

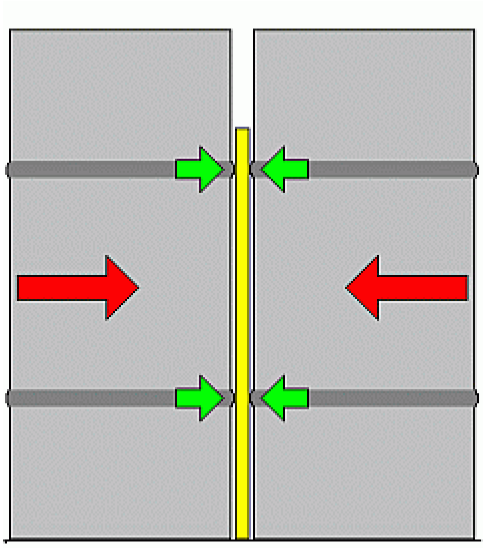
The filling material has to be inserted in both the lengthwise and the crosswise direction. Preventive measures for loss prevention - caused by the inadequacies of commercially available barrels, pails, buckets, drums and similar receptacles - are expensive from the point of view both of materials and in particular of labor.



Problem-free stowage
of barrels with wide corrugations

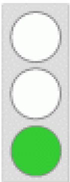
It would be better if more drums were used with wide, tall corrugations, whose lids, closures, drop handles etc. do

not project beyond their diameter.



Load transfer via barrel corrugations

In order to be able truly to prevent denting damage where several barrels are present, hardboard, chipboard or similar flat materials must be inserted in such a way that the corrugations can transfer load via these materials.

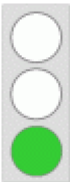


Measures for protecting pallet cargo from harmful pressures

To rule out damage, hardboard is placed (6) between the outer and inner row of barrels and between the inner row of barrels and the vertical metal sheet package. Above the cartons, the forces exerted by the barrels and the sheet package are taken up by squared lumber (8), whose compressive forces are distributed to part of the container side wall via a board (7).

Mixed cargo in a 20' corrugated steel container

This packing example is similar the one discussed above. Positive features are that the cargo is stowed under cover and the dock plate meets the requirements of the German accident prevention regulations.



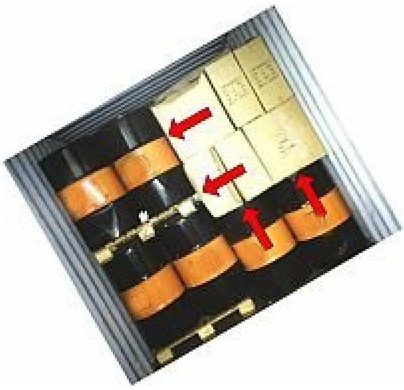
Measures for protecting the cartons from mechanical damage

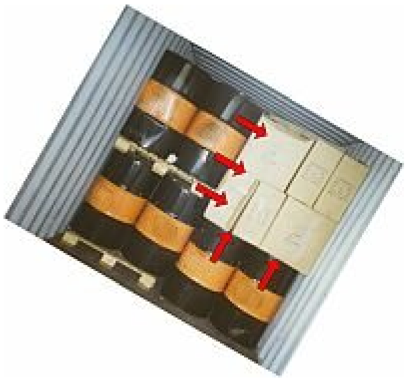
The cable reel (1) has been somewhat differently secured. Variants of this securing can be found in the cable reel section. The blue barrels are raised and the top securing member on the door side has been positioned at the level of the corrugations (2), since these are the parts of the barrels with sufficient loading capacity. Lateral forces which may be exerted by the barrels are transferred to the container walls via the squared lumber (3) and wooden members have been fitted lengthwise for pressure distribution. These measures prevent stress to the carton block.

The situation is different here:

Risk of damage to cartons in a box container

The cartons may be squashed by the barrels. In addition, the bottoms of the cartons may be damaged because no appropriate interlayer dunnage has been provided and they are therefore exposed to high pressures from the barrel rims.

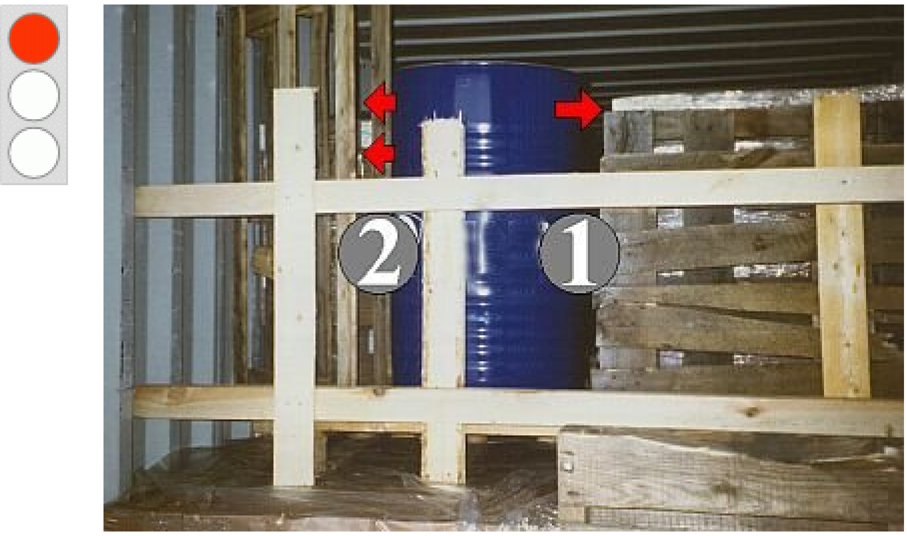




Rolling angles of 30° to each side occur.

The risk of damage becomes clearer if a rolling angle of 30° is assumed for ships and 30,000 alternating loads are assumed to occur during a voyage.

Such carelessness is not unusual during packing:



Inadequately packed 20' box container

Due to the stowage gap (1), the barrel may start to move and damage the cartons to the right of the gap (1) and behind the pallet (2). Packing personnel must always remember that changes in speed and direction occur during carriage which result in considerable inertia forces.

Stowage gaps in a packed 20' container

Even small gaps as at (1) may result in damage under unfavorable conditions. If further cartons were added here, interlayer dunnage would have to be laid on the barrels.

The gaps are still more obvious from this perspective.

Easily visible gaps in a 20' box container

5.3.3.2 Mixed cargo with barrels, example 2

At first glance, this container looks properly packed.

20' box container with packaging and packing deficiencies

On closer inspection, however, a whole series of deficiencies becomes apparent, which are mainly caused by inadequate packaging of the goods.

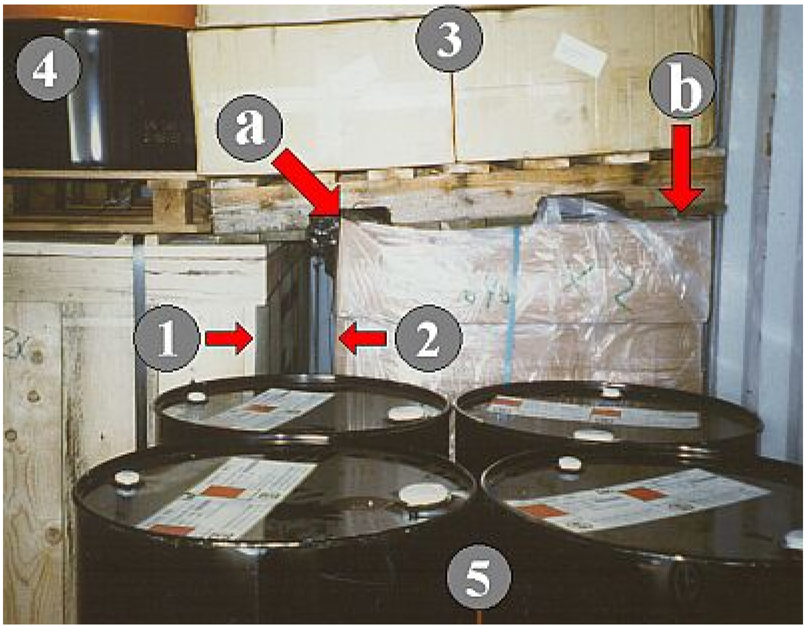
Labeling of the packaging and packing deficiencies

Package (1) is exposed to excessive stress during transport by (2) and (3), because there is no interlayer dunnage. Pallet (2) is not packed flush and has therefore been unfavorably wrapped. Package (3) is inadequately marked, lacking the two upright arrows symbolizing "keep upright". In the case of corrugated board cartons this marking is necessary, because the carton is only sufficiently strong if its corrugations are upright. Since it has not been appropriately marked, the carton has been laid horizontally. The pallet (4) positioned thereon is in a position to exert inadmissible pressures on the packages (6a-b) at (a). A positive feature is that interlayer dunnage of chipboard has been laid on the barrels (5). Package (6) has not been strapped flush on two pallet-like supports. In effect, it consists of two independent packages: namely (6a) and (6b). A pallet has been fastened to the top of package (9), so rendering overstowing impossible without additional pressure-distributing measures. The barrels (7) have been unfavorably packed, causing gaps in the cargo.

In total, these deficiencies increase the stowage factor of the cargo and generally complicate packing and utilization of containers.

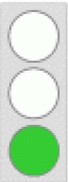
5.3.3.3 Mixed cargo with barrels, example 3

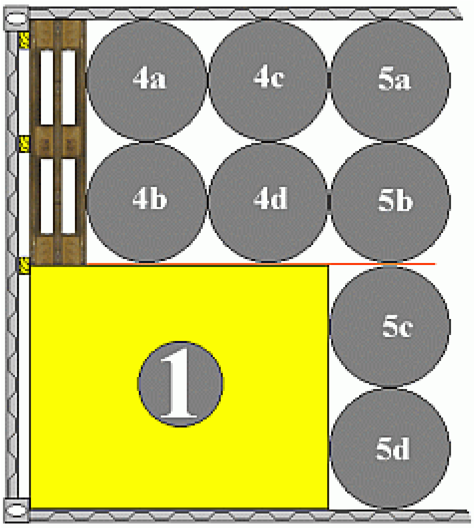
This stowage method cannot be tolerated.

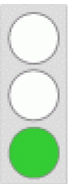


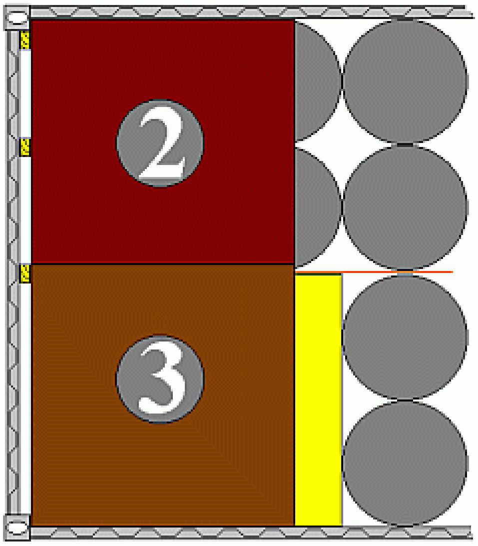
Inadequate packing method in a 20' container

The gap between (1) and (2) should have been closed. The pallet (3) may damage the shipping package (2) at points (a) and (b). The case (1) may crush the cartons (2) and the barrels (4) will cause damage to the packages on pallet (3). It would be best to pack the container differently. The same applies to the barrels (5).









The case (1) should be turned through 90°, whereby barrels 4a-d and 5a-d can be stowed as illustrated. The gaps are filled beforehand or afterwards with wooden beams, pallets and hardboard sheets. The space on top of the barrels 4a-d is brought to the height of the case by filling with lumber or pallets. Packages two and three may then be loaded onto the now flat surface.

5.3.3.4 Mixed cargo with barrels, example 4

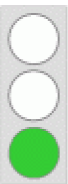
Should this container really be sent off on a journey in this state?

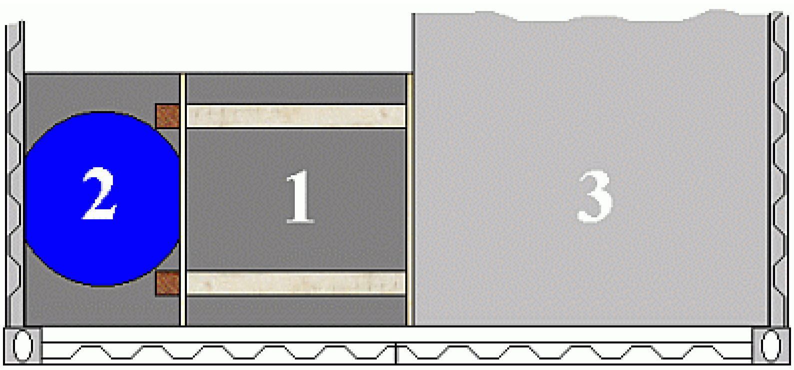
Inadequately packed container

The pallet (1) is not uniformly packed, which is one of the most common errors. The plastic drum (2) and the pallet (3) will destroy one another under stress and the contents of the drum may damage the other goods loaded in the container. Whether wooden members need to be laid under pallet (3) for pressure distribution depends on the strength of the pallet cargo beneath. Any gaps between pallet (1) and left-hand container wall must be filled with bracing.

Subsequent securing measures could include the following:

A wooden board is placed against the inside of the pallet (3). Top dunnage consisting of lumber or boards is laid on pallet (1), boards, and is fixed in place on the one hand by the above-mentioned wooden board and on the other hand by the left-hand container wall. The plastic drum (2) is lashed to pallet (3).





Bracing of the drum against a container side wall

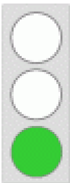
Alternatively, the plastic drum could be pressed against the left-hand container wall with a lattice. The gap between lattice and pallet (3) must be braced. If package (3) is in a position to develop forces exceeding the strength of the barrel (2), bracing must additionally be provided between lattice and left-hand container wall.

5.3.3.5 Mixed cargo with barrels, example 5

Bracing this barrel cargo is very difficult. The addition of cartons and similar, generally pressure-sensitive goods is out of the question.

Gaps still to be filled in a box container

The ideal solution is for a shipping package of sufficient loading capacity, such as a case, to conclude the packing process:



Above and left:
Bracing of a case at floor and lid level

In order to relieve the barrels, the case must be braced against the container wall at least at floor level. Where cargoes are at risk of tipping, bracing in the upper area should also be provided.

5.3.3.6 Mixed cargo with barrels, example 6

Package (1) exhibits typical packaging deficiencies: the upright rectangular cross section of the skids has already resulted in one of them tipping over. A gap between package (1) and the barrel group (2) has not been filled. The stowage personnel originally intended to leave the gap (3) between the upper barrel layer and the container wall. If this container is sent off on its journey in this state, destruction of the contents cannot be ruled out.

The following improvements could have been made:

Package (1) was provided with stable skids and placed on a layer of boards as floor dunnage. A further layer of boards was fitted on item (1) as interlayer dunnage. Both board layers serve to secure the lower barrel layer (a) and

thus alleviate the negative effect of the gap. The barrel layer (b) is braced with squared lumber bracing consisting of several uprights and crosspieces (c). The lower barrel layer has been loaded right up against the door line, but not so the upper barrel layer, so meaning that another pallet must be inserted to fill the lengthwise gap before the door is closed.

5.3.3.7 Mixed cargo with barrels, example 7

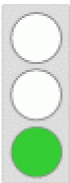
Stowage of these pails between cartons must be considered a packing deficiency. The position of the rear and front pails indicates that not inconsiderable gaps have been left. A disadvantage of all pails, and also of cans, buckets and similar receptacles, is that the handles (1) may press into and damage the bodies of other drums or sensitive items of cargo. It is advisable to use hardboard, boards or similar materials as additional protection and to separate them from other cargoes.

5.3.4 Hazardous materials

5.3.4.1 Examples

There are so many regulations relating to hazardous materials, and they are subject to such regular amendment, that they cannot be dealt with in this Handbook. This section will merely point out a few of the problems relating to these goods.

The general introduction to the IMDG Code gives important information about packaging. Good packaging is half the battle when it comes to cargo securing. Correct packaging should be the norm, but sadly is the exception.



Drum for hazardous materials, containing a corrosive substance, which evolves flammable gases on contact with water.

[N.B.: The drum itself, filling level and labeling would warrant a green light. However, the attempt to form a cargo unit warrants the red light.]

"Rule 3 - Packaging" of the general introduction states, among other things:

1 Dangerous goods should

1 be carefully packaged and in good condition;

2 be of a nature such that internal surfaces with which the contents can come into contact cannot be subjected to dangerous attack, and

3 be resistant to the stresses produced in handling and transport at sea.

3 Receptacles which are filled with dangerous liquids should, at the filling temperature, have a liquid-free volume which makes sufficient allowance for the highest temperature occurring during normal carriage.

7.3.3 Markings on shipping packages containing dangerous goods must be applied in such a manner that the markings are still discernible on shipping packages which have spent at least three months in seawater. When considering suitable marking methods, the durability of the packaging material and the surface of the shipping package should be taken into account.

Non-regulation cargo unit

10.18.2 packages that contain hazardous goods, that are permitted to be transported in accordance with the code, may only be transported in unit loads if the following conditions are fulfilled.

10.18.2.1 It may occur that the packages in a unit load will need to be separated. In this event, it must be ensured that the individual packages can be handled safely.

10.18.2.2 The unit loads should be compact, have as regular a form as possible, and for the most part, vertical sides. The top of the unit load should be level. It must be possible to stack the unit loads. They must be constructed and secured in such a way that it is unlikely that the individual packages can become damaged.

10.18.2.3 The unit loads must be sufficiently strong to withstand repeated loading and stowing operations and they must be able to bear unit loads with a similar specific mass which are stacked on them to a height commonly occurring during transportation.

10.18.2.4 The material used to bind a unit load together must be compatible with the substances contained in the unit loads and must remain effective under the influence of moisture, extreme ambient temperatures and sunlight.

10.18.3 The individual shipping packages and the unit load must be marked in accordance with sections 7 and 8 of the general introduction.

10.18.4 Unit loads must be directly liftable with a forklift truck or other suitable equipment. Unless generally visible, lifting points must be marked on the unit load.

The CTU packing guidelines contain, among other things, the following regulations:

4.2.5 Dangerous cargoes should only be handled, packed and secured under direct and identifiable supervision of a responsible person who is familiar with the legal requirements and the risks involved and who knows the measures that should be taken in an emergency.
4.2.6 Suitable measures to prevent fires should be taken, including the prohibition of smoking in the vicinity of dangerous cargoes.
3.2.7 In order to avoid cargo damage from moisture, wet cargoes, moisture-inherent cargoes or cargoes liable to leak should not be packed with cargoes susceptible to damage by moisture. Wet dunnage, pallets or packaging should not be used. In certain cases, damage to equipment and cargo can be prevented by the use of protective material such as plastic films.


Damaged bucket - non-regulation cargo unit

3.2.8 Damaged packages should not be packed into CTUs unless precautions have been taken against harm from spillage or leakage (see 4.2.7 and 4.3.1 for dangerous cargoes).
4.3.1 Special care should be taken during handling to avoid damage to packages. However, if a package containing dangerous cargoes is damaged during handling so that the contents leak out, the immediate area should be evacuated until the hazard potential can be assessed. The damaged package should not be shipped. It should be moved to a safe place in accordance with instructions given by a responsible person who is familiar with the risks involved and knows the measures that should be taken in an emergency.


Dangerous cargo with traces of liquid

4.2.7 Packages of dangerous cargoes should be examined and any found to be damaged, leaking or sifting should not be packed into a CTU. Packages showing evidence of staining etc. should not be packed without first determining that it is safe and acceptable to do so. Water, snow, ice or other matter adhering to packages should be removed before packing. Liquids that have accumulated on drum heads should initially be treated with caution in case they are the result of leakage of contents. If pallets have been contaminated by spilt dangerous cargoes they should be destroyed by appropriate disposal methods to prevent use at a later date.


Non-regulation cargo unit

4.2.8 If dangerous cargoes are palletized or otherwise unitized they should be compacted so as to be regularly shaped, with approximately vertical sides and level at the top. They should be secured in a manner unlikely to damage the individual packages comprising the unit load. The materials used to bond a unit load together should be compatible with the substances unitized and retain their efficiency when exposed to moisture, extremes of temperatures and sunlight.
4.2.9 The packing and method of securing of dangerous cargoes in a CTU should be planned before packing is started.


How well was this planned?

Nothing good ever comes of gaps in a container, especially not if no interlayer dunnage is used.

The result of such packing methods may look like this:



Consequence of stowage gaps in containers

The Container Packing Certificate must, among other things, confirm correct packing behavior. This states:
All packaged have been externally inspected for damage, and only sound packages have been loaded.
4.3.2 If a leakage of dangerous cargoes presents safety or health hazards such as explosion, spontaneous combustion, poisoning or similar danger, personnel should immediately be moved to a safe place and the Emergency Response Organization notified

4.3.3 Dangerous cargoes should not be packed in the same CTU with incompatible cargoes. In some instances even cargoes of the same class are incompatible with each other and should not be packed in the same unit. The requirements of the IMDG Code concerning the segregation of dangerous cargoes inside CTUs are usually more stringent than those for road and rail transport. Whenever a combined transport operation does not include transport by sea, compliance with the respective inland transport regulations, such as ADR, RID, ADN and ADNR, may be sufficient. However, if it cannot be guaranteed that no part of the transport operation will be by sea, the segregation requirements of the IMDG Code should be strictly complied with.
4.3.4 When dangerous cargoes are being handled, the consumption of food and drink should be prohibited.
3.2.11 Any special instructions on packages, or otherwise available, should be followed, e.g.:

- *cargoes marked "protect from frost" should be packed away from the walls of a CTU;*

- *cargoes marked "this way up" should be packed accordingly;*

- *maximum stacking height marked should not be exceeded; and*

where practicable, markings on packagings should conform to ISO 780-1983.

5.3.4.1 Examples

This container stuffed for a voyage overseas was packed with hazardous materials, among other things. In accordance with legal requirements, a signed Container Packing Certificate was also provided, which certified that the container had been properly packed and the cargo adequately secured. It is incomprehensible how anyone could make such a statement, given the packing situation illustrated.

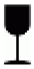
Inadequately packed container with some hazardous materials

Incorrectly packed container with dangerous cargo

Class 3 and class 9 hazardous materials are laid on top without any securing whatsoever. Are the packing personnel completely unaware of the risks created here? The majority of the packages consisted of relatively expensive industrial goods.

The section of the CTU packing guidelines entitled "On completion of packing", states, among other things, that care should be taken during the final stages of packing a CTU, so far as is practicable, to build a secure face of the cargo so as to prevent "fall out" when the doors are opened. If there is any doubt about that, additional securing measures are necessary. It is also pointed out that a container on a trailer usually inclines towards the doors and that cargo may move against the doors due to jolts etc., during transport.

For road transport of the container illustrated, the applicable regulations on hazardous materials are also definitive. These require that the individual parts of a cargo of hazardous materials be so stowed on the vehicle and secured by suitable means that they can change position only slightly relative to one another and relative to the walls of the vehicle. It is additionally stated that these regulations also apply to containers and that shipping packages labeled with the "Fragile" symbol must be protected against damage by other shipping packages.



Fragile

It is additionally stated that shipping packages carrying hazardous materials must be kept separate from the other shipping packages. This regulation has also been contravened.

Relevant regulations are also to be found in GGVSee. Contravention of legal requirements may incur fines.

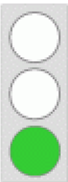
Under certain circumstances, § 130 of the German Administrative Offences Act provides for fines of up to a 500,000 €, if the administrative offence is accompanied by punishable action.

5.3.5 Cable reels with other cargoes

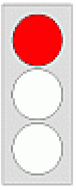
The packing deficiencies at the container end wall are continued throughout. The incompletely packed pallet is not held securely on the cable reel by the interlayer dunnage consisting of two small boards (1) laid lengthwise.

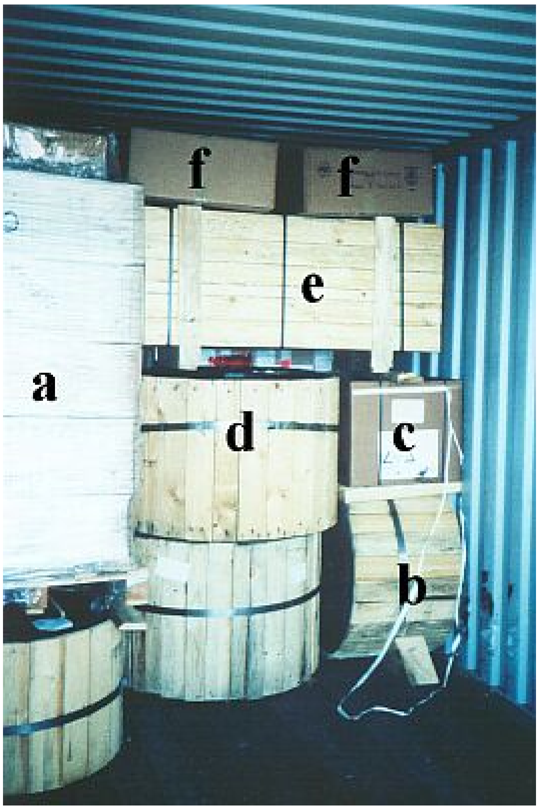
Inadequate interlayer dunnage

The wooden members should have been larger and laid crosswise (see left).

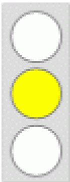


Interlayer dunnage made from strong planks





Various packing deficiencies



Remedied deficiencies

The method used to pack the container is deficient. However, the interlayer dunnage of planks (1) does give the pallet (a) a secure footing. The cable reel (b) has been stowed with its axis crosswise, which is not very advantageous when it comes to further packing. Even less advantageous is the use of the wedge, which prevents the introduction of further cargo, since additional materials would then be necessary for gap-free stowage. Furthermore, the wedge has been incorrectly cut, since only the end grain is available for nailing. This defect has been corrected at (2): now nails can be hammered into the face grain. The package (c) stands loose on its support and on the cable reel. It could be made reasonably stable by passing the strapping around the wooden skid (3) and stowing the package compactly among other cargo. The package (c) would be damaged by the case (e), a situation which can only be remedied by sufficient interlayer dunnage (4), laid on cable reel (d) and braced against the container wall by boards or the like positioned underneath. If the cartons (f) are very sensitive, interlayer dunnage (5) must be laid on the case (e), though this can be omitted if the box's belt battens are not in a position to damage the cartons.

Irrespective of whether or not cartons carry two upright arrows, they should be positioned "right way up" (6).

5.3.6 Cases and crates with other cargoes

5.3.6.1 Cases and crates with other cargoes, example 1

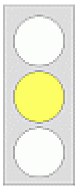
Numbering of certain packages for error analysis

Packages (2) and (3) may slip towards the container side wall (1). Package (4) may slip and tip and damage packages (5), (6) and (7) and other shipping packages. Repeated to-and-fro movements will damage not only the cargo but also the container itself. Even adjacent containers may be affected.

Packing errors become particularly clear if the container is tilted.

Risks at 30° tilt

Improvements may be achieved by a small amount of restowing and the use of squared lumber and boards, but the result is by no means optimal:



Reasonably usable result achieved by restowing and bracing

With the method shown, the container wall is subjected to point-loading, as is the plywood case if it is not braced directly in the area of the front end wall. The latter measure results in plate action, so that no further damage would be likely to arise.
At any rate, boards or the like should be inserted at the side wall of the container for pressure distribution.

Possible variant of a well packed section

Only with careful stowage planning can sensible packing and securing be achieved. It remains to be seen whether the suggestion given here is the best, but at least cargo damage should no longer occur. This Figure is merely intended to illustrate the possibility of a compact stow.

However, optimum stowage and securing can always be achieved by timely stowage planning. According to the CTU packing guidelines, there is an obligation to do this:

> *3.1.4 Packing should be planned before it is started. This should make it possible to segregate incompatible cargoes and produce either a tight or secured stow, in which the compatibility of all items of cargo and the nature, i.e. type and strength, of any packages or packaging involved are taken into account. The possibility of cross-contamination by odor or dust, as well as physical or chemical compatibility, should be considered.*

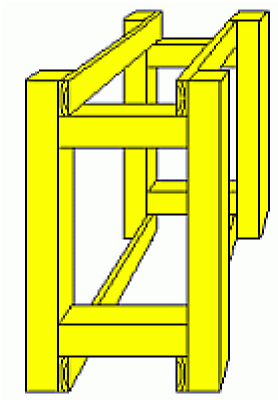
It is almost always possible to draw stowage plans. Other options, such as previous "mapping" with "container templates" and similar methods have already been dealt with under the heading "Basic stowage rules and general notes".

Sometimes it is just little things which can turn an inadequately packed container into a satisfactorily packed container. This picture shows a well thought out solution:

Well packed and secured section

Bracing has been inserted between the two cases in the bottom layer, the crosspieces of the bracing finishing flush with the floor and the top of the case. In this case, this is good, since the crosspieces introduce the forces satisfactorily into the lid areas. In the floor area, this is no longer ensured due to the different types of box.

It has been stated in the general section that the following arrangement of wooden members is the best for bracing, to ensure that the wooden members do not cave in at the face/end grain interface. This basic rule is particularly applicable to heavy cargoes.



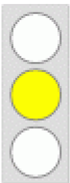
Bracing variant for heavy cargoes

However, there are exceptions to every rule: In the packing example shown, it would have been appropriate to use a hybrid which was flush at the top but not at the bottom.

The squared lumber members used to brace the gap between the cases in the second layer have been deliberately raised, so that the forces are introduced into the case bottoms. To protect the cargo, plywood interlayer dunnage has been inserted between the cartons in the upper area of the section. The tipping forces from the large plywood case acting on the cartons were absorbed in the upper area by inserting squared lumber between this upper area and a wooden board placed against the container wall to distribute the pressure.

5.3.6.2 Cases and crates with other cargoes, example 2

There is a slight risk here of the wooden case damaging the pallet by tipping. The case is secured at floor level against sideways shifting, since pallet bottom and case bottom lie at the same level and virtually touch. However, there is a risk for the pallet cargo because the cartons are lying down and no account has been taken of the handling symbols.



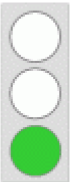
Compact stowage method for a container section with low risk of damage due to tipping of the case.

Disregarding the handling symbols on the pallet cargo

All risk of tipping of the case could definitely have been prevented by insertion of a small bracing member before the pallet was loaded.

Simple bracing for securing the case against slipping and tipping

Here, the pallet was packed taking the handling symbols into account, covered with a plywood board (1) and strapped.



Expertly packed pallet

If this pallet is positioned in front of the bracing shown above, the case cannot have a damaging effect on the cartons on the pallet.

Alternatively, it would have been possible to dispense with the bracing behind the pallet and to fit some narrow

beams (2) between case and pallet:

Separating the pallet from the case using wooden beams

5.3.6.3 Cases and crates with other cargoes, example 3

The gaps mean that the cargo can be damaged:

Risk of damage due to gaps

The cases and cartons on the pallets can be damaged as a result of the gap (1). First of all, the cartons in the area (2) are damaged. It can be seen at (3) that the pallet has not been packed flush.

Gaps mean that inertia forces can cause damage.

Secure bracing could look like this:

Bracing of a stowage gap with squared lumber

If it is assumed that the upper, inner corner of the carton pallet could be damaged by tipping forces from the box pallet, the right-hand wooden upright should extend higher and be braced against the container wall:

Additional shoring of bracing against the container wall

5.3.6.4 Cases and crates with other cargoes, example 4

What will happen to the contents of the mail bags when a case and six barrels fall on them?

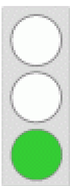
Mail bags, at risk from case and barrels

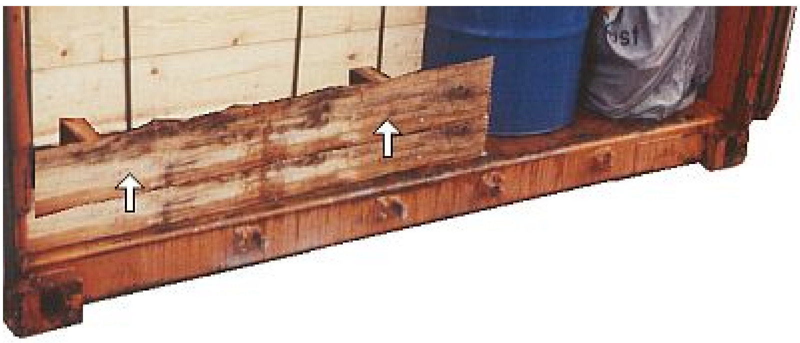
The movement of the sea would gradually create more and more space between the barrels and cases, resulting in mutual damage. In the longitudinal direction, the case is only braced towards the door.

Incorrectly positioned bracing

The bracing should have been positioned in the area of the case bottom ...

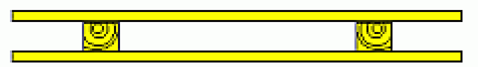
.... As here:



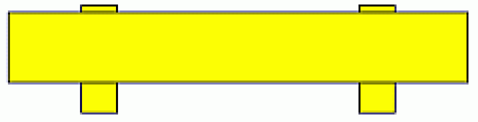


Wooden bracing, positioned in the area of the case bottom

The simplest thing to do is to take the necessary measurements and to build appropriate bracing outside the container.



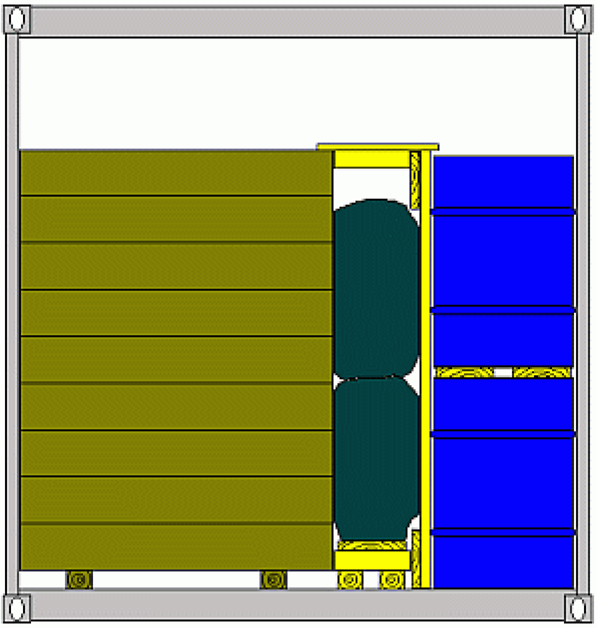
Bracing for the door area - plan view



Bracing for the door area - front view

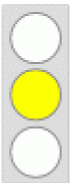
The bracing is positioned in front of the case and the left door leaf is closed. If it has been sufficiently accurately made, no further measures will be necessary.

Securing for case and barrels which at the same time allows protection of the mail bags could look like this:



Protected space:
mail bags inside bracing for case and barrels

A simple lattice consisting of two vertical and two horizontal boards is positioned against the inner side of the barrels. Bracing is provided in the bottom and lid areas of the case. In this way, the mail bags are also protected from condensation on the container side walls.



If the mail bags are not at any risk from condensation water, the remaining space between case and door may serve to accommodate further bags.

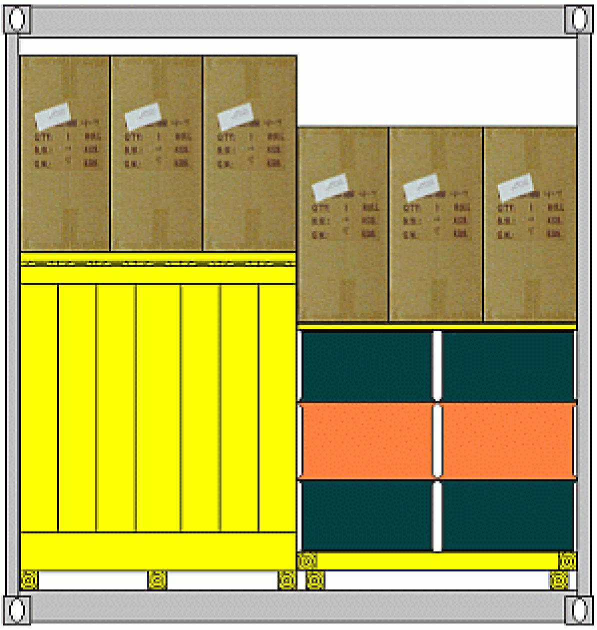
Mail bags in the door area

5.3.6.5 Cases and crates with other cargoes, example 5

If this container is left stowed like this, it is almost certain that considerable cargo losses will eventually arise during the course of the voyage.

The wooden case (1) 2,856 kg in weight will crush the cartons (2) and ultimately even be damaged itself. The barrels (3), with a mass of approx. 220 kg each, will destroy the cartons (4) and possibly even leak. Further damage will occur in the front part of the container.

This is how the container could have been well packed:

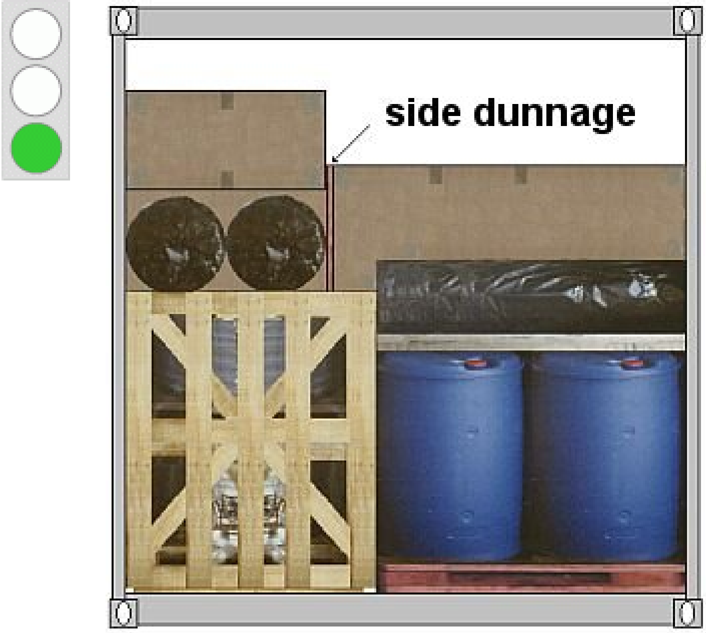


The heavy wooden case is stowed tightly against the left-hand container wall. At floor level it is supported against the right-hand container side wall by wooden bracing. The barrels are loaded onto this bracing. Any remaining gaps are filled with material of sufficient loading capacity. Interlayer dunnage of wooden boards or the like is placed on the barrels, which additionally secures the case in the upper area against tipping forces and provides a clean supporting surface for the cartons to be loaded thereafter in stepped arrangement.

5.3.6.6 Cases and crates with other cargoes, example 6

The wooden crate has been produced without diagonal bracing. The incorrect design was partly responsible for the deformation. What pallets (2) and (3) are intended to achieve is unclear.

In addition, the loading bed has been positioned incorrectly - it must adjusted to the level of the container floor.



Improved packing

A different crate design and a modified packing method would have resulted in satisfactory packing of the container.

5.3.6.7 Cases and crates with other cargoes, example 7

Due to the low loading capacity of the plastic drums and the stowage gaps, the voyage could be a "wearing" one, since the gaps between sections 1 & 2 and 3 & 4 are too big:

Inadequate packing in a 20' standard container

The decision as to whether the plastic drums should be stowed at top or bottom depends essentially on a comparison of the case and drum masses. Primarily, the basic stowage rule "light on heavy" should be followed. Where the masses are virtually identical, the decision to adopt a particular stowage method should be based on the principle of "dry on wet", if the drums contain liquids. This principle is of little relevance in the case of pasty or powdery contents.

Depending on the contents of the drums, an acceptably packed container could look like this:

Gap-free container section using pallets for securing

The plywood cases are stowed to the left and right against the container side walls and the gap is filled with vertically positioned pallets (5). Interlayer dunnage consisting of walking boards (6) is laid on the cases, and the plastic drums are loaded on that. These are separated from the cargo to be packed subsequently with boards (7) fitted into the corrugations.

Appropriate cargo dimensions ensure gap-free packing

A stow is more cost-effective if the package dimensions fit the container. All that is needed here is for interlayer dunnage to be put in place and the drums to be separated from sections still to be packed.

Bracing of gaps in a 20' container

The plastic drums (8) can be stowed in the bottom layer, if the plywood cases in the second layer are no heavier. It is essential to lay interlayer dunnage made from walking boards (9) or similar materials on the drums. The pallets with the plywood cases attached to them are placed in the second layer against the container side walls. The gap (10) remaining in the middle is braced.

Appropriate cargo dimensions ensure gap-free packing

Where masses are relatively great or relatively high inertia forces are to be anticipated, sections inside the container must not be separated by means of boards fitted into the corrugations, since the container may otherwise be damaged. A substitute method uses lattices, which are supported against parts of the container which have sufficient loading capacity. At any rate, the boards must be secured against sliding down.

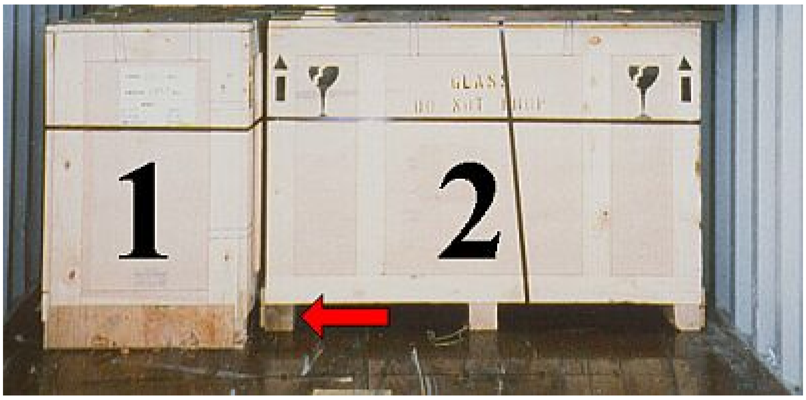
5.3.6.8 Cases and crates with other cargoes, example 8

Considerable packaging and packing deficiencies

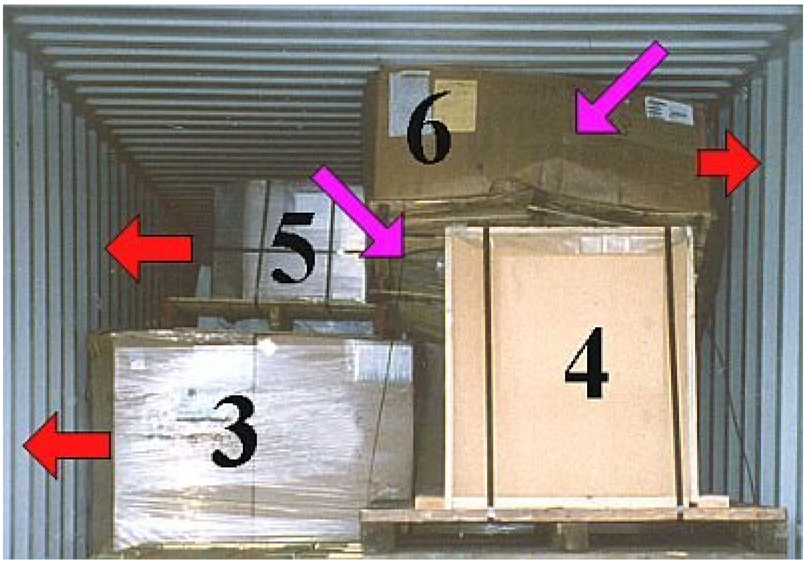
The fundamental deficiencies are:

Shipping package 1 can only be picked up with ground conveyors from two sides. With the stowage method illustrated, it was either additionally turned round or it was picked up with the forks under the cross beams, being "pushed in" with the forks between beam and container floor, thereby risking damage to the package and the container floor.

Package 2 lost a wooden member during handling and has been temporarily "jacked up"; in addition it is incorrectly marked: the individual arrows indicate the "top" of this package. Since the contents are made of glass, it must have been to say that the package should be carried upright. However, such a stowage instruction should be expressed by two upright arrows.



Unfavorable case skid on 1, broken wooden member and incorrect marking on 2



Incorrectly packed, incorrectly constructed shipping packages

Package 3 reaches down to the container floor and is therefore at risk of tipping. For this reason alone, the gap relative to the container wall should have been filled.

Shipping package 6 was handled "brutally" and was crammed into the container over package 4. Shipping packages 4 and 5 are not suitable for transportation as they are, since both are strapped onto pallets with steel strapping, despite the fact that their dimensions do not allow for flush loading. One steel strap is already torn. In addition, adequate edge protection has not been used.

Fully palletized cargo simplifies packing in containers carrying mixed consignments . However, when properly secured, the packages illustrated here incur higher costs.

5.3.7 Palletized cargoes, mixed cargo

5.3.7.1 Palletized cargoes, mixed cargo, example 1

Even apparently small deficiencies may cause considerable damage during the packing of containers.

Inadequate packing in a general purpose container

The gap to the left of shipping package 1 has been "braced" with a few "chucked-in" pieces of waste lumber. One of the wooden parts of the prop under shipping package 3 has broken off. A piece of waste squared lumber has been put temporarily in its place. A gap has been left between the shipping package 3 and the left-hand container wall and between packages 4 and 5.

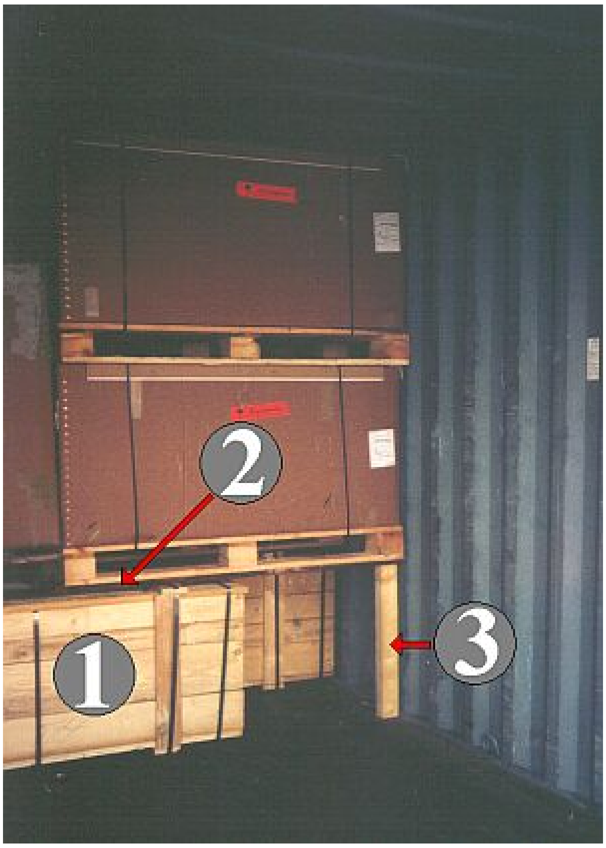
Remedied packing deficiencies

The packages (1) and (3) have been stowed tight against the container wall, and the skid under package (3) has been repaired. The gap then arising between packages (1) and (2) has been filled with squared lumber. The gap between package (3) and packages (4) and (5) has been filled with an airbag. The airbag can only be used in the manner illustrated if the shipping packages have sufficient loading capacity and there is no "air" between the carton walls. Otherwise, plywood sheets or the like have to be used for pressure distribution.

5.3.7.2 Palletized cargoes, mixed cargo,

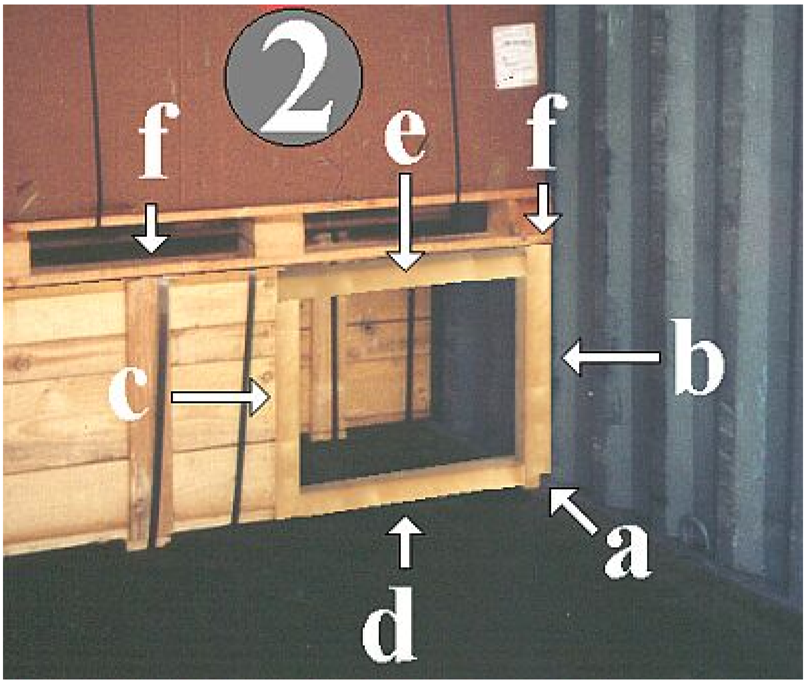
example 2

Even if the packers continue to pack the container compactly, using the squared lumber upright constitutes a risk.



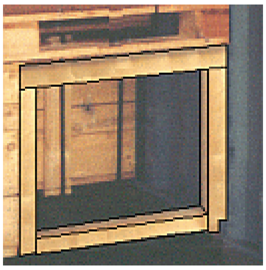
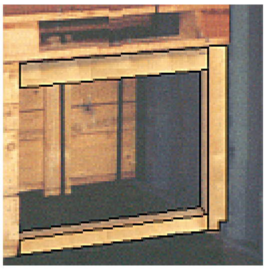
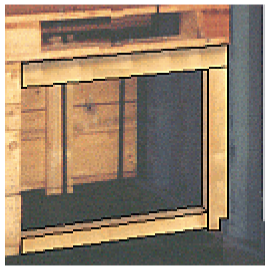
The upright (3) is too long and therefore lifts up the package (2) so it doesn't lie flat on the case (1). Slight jolting during transport could loosen the upright (3) and the package (2) might sag into the gap and jam there.

The securing deficiencies may be remedied without much effort.



The upright matches the height of the case and has been recessed (a) at the bottom end so that the profile of the bottom side rail does not hinder the upright from fitting into a container corrugation (b). The upright is fixed using another upright against the case (c) and two crosspieces (d) and (e), in such a way that it cannot slip out of the corrugation. The package (2) thus rests evenly on the upright and the case (f); at the same time, the case (1) is secured.

There is a series of possible ways of fixing the upright, some of which are illustrated here.

Possible ways of fixing the upright

5.3.7.3 Palletized cargoes, mixed cargo, example 3

The tube coils could be damaged by the pallet stowed on top of them. In addition, the arrangement of the shipping packages makes further packing difficult.


Very risky packing of a box container

Interlayer dunnage of boards or beams supported by squared lumber simplifies the stowing of further packages. The stowage gap was left between the two pallets as a result of restowing and has been filled using two plywood sheets for pressure distribution and an airbag.

Risk reduction using wooden interlayer dunnage and an airbag to fill the stowage gap

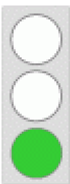
5.3.8 Big Bags, mixed cargo

Big Bags are primarily used for cargoes which have a high weight per unit volume and thus a low stowage factor. The same almost always applies to palletized cargoes of paper bags.

Big Bags and palletized paper bags in a 40' container

If 1,150 mm x 1,150 mm pallets are used, the container floor can be virtually completely filled. In the door area, a wooden lattice of squared lumber and/or boards fitted between the corrugations serve to close off the stow.

The wastage of stowage space is very clear in this example. Although the full capacity by weight of the high-cube container has been utilized, only half its volume has been filled.



Big Bags and palletized paper bags in a 20' container

If the same batch of cargo had been packed in a 20' container with a somewhat higher load-carrying capacity, the container's capacity could have been fully utilized in both weight and volume terms. This would have resulted in excellent utilization of the container as its ratio of weight capacity to cubic capacity is virtually identical to the cargo's gross stowage factor. As for practical packing issues, interlayer dunnage of wooden dunnage boards was laid

between the first and second layers. In this case too, a small residual gap in the stow in the door area can be finally secured with a lattice of wooden dunnage and/or squared lumber.

Packing 40' containers with Big Bags and other cargo can only be economic and practical if relatively light, bulky cases with a high stowage factor are stowed together with Big Bags with a low stowage factor. This combination of cargo allows the capacity of 40' containers to be fully utilized in both weight and volume terms.

Alternating packing sequence: cases, Big Bags etc.

5.3.9 Cartons

5.3.9.1 Cartons only

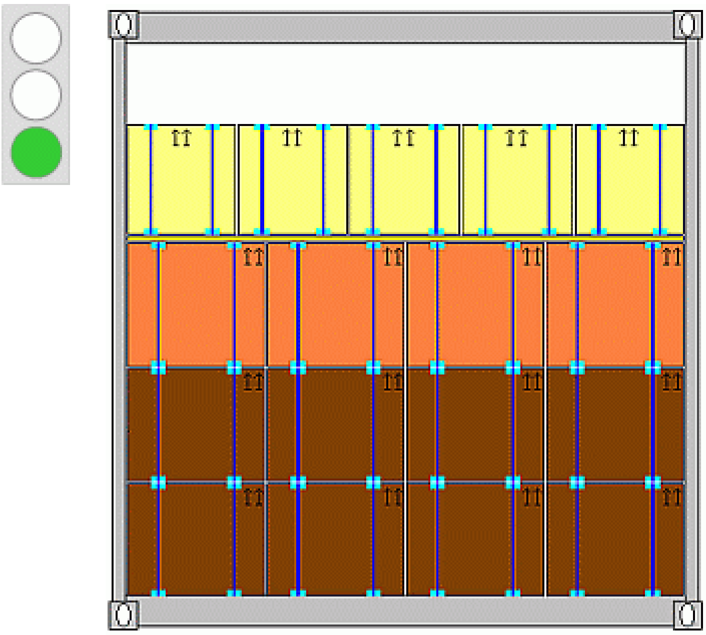
Pallets which have not been packed flush inevitably result in gaps in the stow which can only be eliminated at the cost of considerable labor and material. There is only one solution in this case - unpack the pallet and stow manually.

Container not entirely correctly packed due to packaging

The packages are here neatly packed edge to edge, as this is the only way for the underlying layers to withstand the forces from above; since this was not possible for the final layer due to the package dimensions, plywood interlayer dunnage had to be laid beneath the final layer.

The shortcomings in strapping due to the lack of edge protectors will not be discussed any further at this point. However, and this is why the traffic light is at amber, it is to be suspected that the cartons are not correctly oriented. The appearance of the cartons and the adhesive taping could indicate that the flutes in the carton board are not vertical, but horizontal. Again: Adequate marking is an indispensable component of the packaging.

This is correct:



Correctly packed container with ideally harmonized packages

The lower layers are packed edge to edge, i.e. "flute" to "flute" in correctly constructed cartons. Since this is not possible in the final layer, interlayer dunnage ensures adequate distribution of pressure to the underlying layers. The remaining empty space at the top of the container presents no risk to the cargo as the package dimensions mean that there is no risk of their "popping up" out of the stow.

Additional measures such as side dunnage, nonwoven fabric covers etc. could be necessary if there were any risk that the packages could be damaged by container sweat.

5.3.9.2 Cartons, mixed cargo

5.3.9.2.1 Example 1

5.3.9.2.1 Cartons, mixed cargo, example 1

"Bulk loading" of general cargo in a 20' steel corrugated container

Package 1 has a mass of 492 kg, while package 3 has a still greater mass. The packages 2 could fall into the gaps beneath or be crushed between 1 and 3 as a result of shipping stresses. Packages 4 and 5 are at considerable risk of damage. Package 6 can be seen to be inadequately packaged: steel strapping should be avoided on cartons. The lack of edge protectors has meant that the straps have already cut into the carton.

The pallet and board are useless in terms of cargo securing.

It is economically unacceptable for considerable investment to be made in the manufacture of goods if these efforts are wasted during shipment.

"Bulk loaded" general cargo

With this container, all that can be hoped is that the ship has a calm voyage as there will otherwise be little left of the household goods in these packages.


Removal container inadequately packed with household goods

5.3.9.2.2 Cartons, mixed cargo, example 2


Packaging and packing deficiencies

Most of the gaps in the packing are attributable to inadequate packaging and palletization. Package a has been damaged during stowage. Someone has obviously used the carton as a step in order to stow the upper layer of cartons manually.

A better stow could be achieved by unpacking the "palletized" cargo and stowing the packages conventionally.

Gaps in the load due to inadequate palletization

The same problem again: the inadequately packed and wrapped pallets are virtually impossible to secure economically. Unpacking and manual stowing is virtually the only way to secure the cargo sensibly.

As already explained in the packaging section, it is essential

- to select appropriately sized packaging containers,
- to provide pallet bases which are suitable for container transport,
- to provide adequate edge protection when strapping, and
- to provide strong shrink wrapping or other wrapping around the pallets or bases.

The following example reemphasizes these basic rules:

Packaging and palletization deficiencies promote damage

Pallets (a) and (c) have been strapped together (b) to form a cargo unit. However, the lack of edge protectors and

poor application of the strapping promote cargo slippage. Pallets (d) and (e) are likewise poorly strapped and rest on very "wobbly" feet (f). It is better if the pallet blocks are as wide as possible. Extended periods of bad weather during a voyage make damage virtually unavoidable.

Proper palletization facilitates container packing and securing of the cargo in the container.

No changes were made to the cargo dimensions. The cartons were merely set edge to edge and in some cases different pallet bases were used. In this manner, in conjunction with suitable strapping, the cargo can be accommodated securely in the container.

A structure of walking boards and squared lumber offcuts was fabricated outside the container and used to brace the gap remaining in the center of the cargo. The same effect can be achieved with pallets which are no longer required.

Apparently insignificant errors can result in major damage.

The package (a) has not been stowed against the container side wall. Package (b) has only a very small bearing area where indicated. The gap (c) has not been filled. There are similar shortcomings throughout the container. Depending upon the mass and strength of the packages, interlayer dunnage of wooden sheets or boards would be necessary at certain points.

5.3.9.2.3 Cartons, mixed cargo, example 3

An ordinary, everyday situation:

Unfavorable pallet dimensions in a 20' ISO export container

The pallets used measure 800 mm x 1,200 mm and are thus not suitable for container use. The pallets are also not neatly packed and include gaps (1). Due to their design, they only have a strip-like bearing surface (2) which consequently generates high pressures. The edge of pallet (3) is sticking out beyond the cargo. Moreover, the strapping is so badly placed that it could break during forklift truck handling. The gaps between the pallets and at (4) between container side wall and pallet (3) and are too large.

Considerable effort would be required in order to achieve a compact stow without gaps.

Excessively large number of pallets to fill gaps

Pallet (2) ought to be lifted up to allow placement of interlayer dunnage to distribute the pressure. Ten pallets would be required to fill the gaps (5) with pallets. Such a large number just for these gaps is unacceptable.

It is specifically stated in point 3.2.12 of the CTU packing guidelines that, when deciding on packaging and cargo securing material, it should be borne in mind that some countries enforce a garbage- and litter-avoidance policy. It is furthermore stated that this may lead to limitations on the use of certain materials and imply fees for the recovery of packaging.

A compact stow achievable due to the dimensions of the cargo is the most economic method of cargo securing.

Compactly stowed container - partly staggered

Although packing was carefully carried out and gaps were avoided or filled, the traffic light is still at red.

Inadequate securing of a relatively large gap in door area

The squared lumber member placed between the container corrugations to block the gap remaining in the door area is not adequate. The lumber crosspiece used could not withstand inertia forces generated by the cargo, especially if this container were stowed athwartships on board ship or if precarriage or onward carriage were by rail.

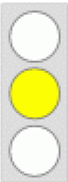
Risk of damage to container corrugations by squared lumber

The squared lumber could be forced out, probably also resulting in damage to the container walls.

5.3.9.2.4 Cartons, mixed cargo, example 4

The gap in the stow at (1) must be filled. The textile rolls (2) could possibly be damaged by rolling to and fro.

Packing deficiencies in a stow of cartons and textile rolls



Provisional securing by tie-down lashing

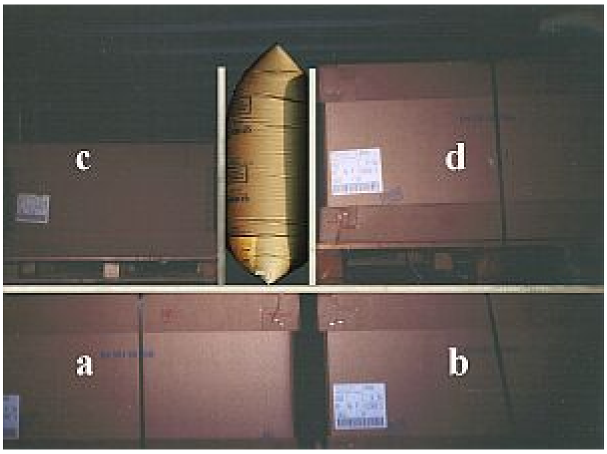
Subsequent repacking of textile rolls is difficult. Gaps remain at (3) and (4). However, if the rolls are lashed down tightly enough, they will remain in the cantline. If such securing is to be feasible, appropriate lashing points must be present and the lashing means must be attached to them in advance and lifted up as packing proceeds.

5.3.9.2.5 Cartons, mixed cargo, example 5

The gap between the upper left-hand package and the container side wall cannot be left as it is. Moreover, no interlayer dunnage has been laid .

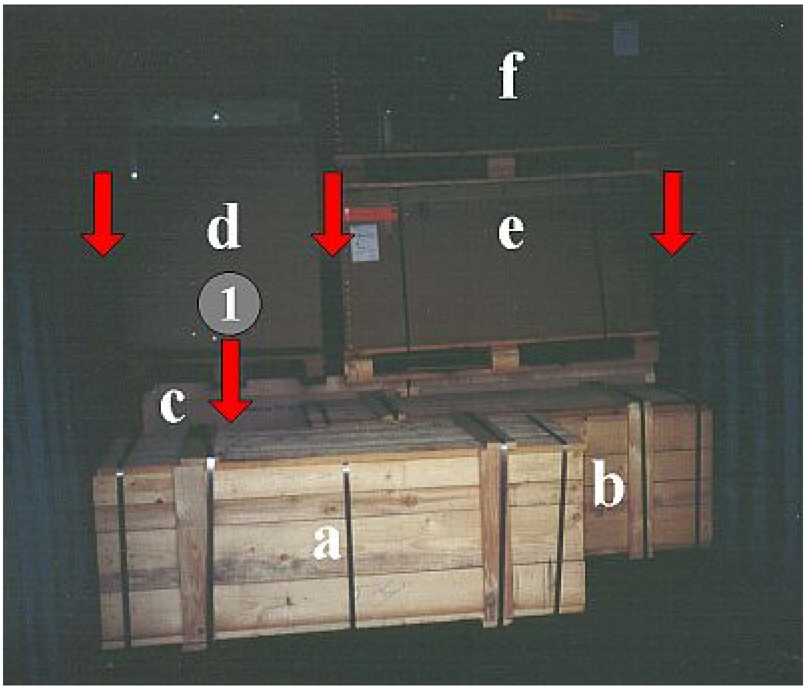
Gaps in the load constitute a transport risk.

Filling gaps with airbags



Interlayer dunnage should be laid between packages a & c and b & d. The inner sides of packages c and d are protected from point loads with sheets or boards and the gap between the items of cargo is filled with an airbag.

In this case too, the gaps in the load can result in damage.



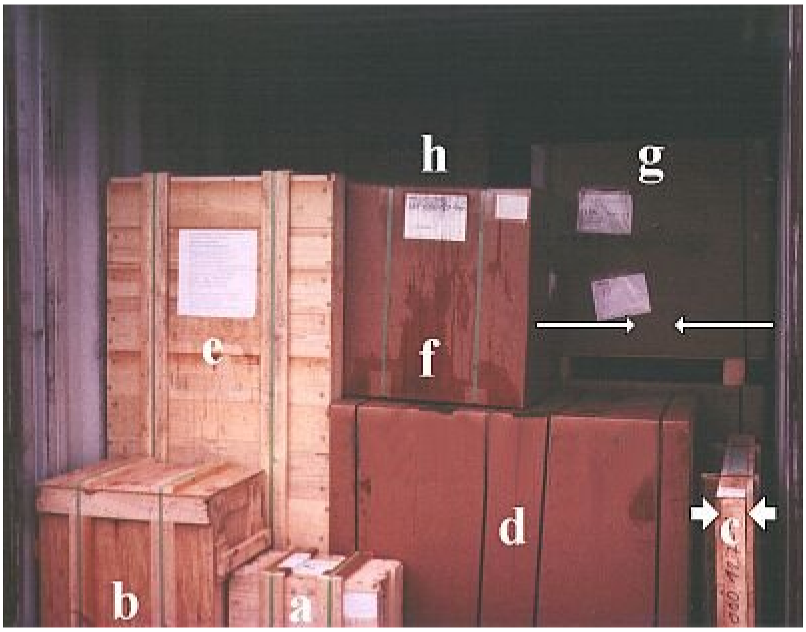
Gaps in the stow are the root of all evil.

The gaps behind case (a) and between case (b) and the left-hand container side wall are particularly critical, but the

other gaps (red arrows) may also be the root cause of damage. Steps could have been taken to prevent damage by laying dunnage on package (c), onto which packages (d) and (e) could have been placed. No interlayer dunnage would be required between (e) and (f), provided that the bearing area of the pallet-like base is sufficiently large and package (e) is not excessively sensitive.

A good alternative would have been to pack cases (a) and (b) on squared lumber supports placed lengthwise on the right and left of the container. Package (c) could then also have been placed lengthwise in the middle. The squared lumber supports would have had to be dimensioned so as to offset the difference in height between (a) and (b) and package (c). The other packages could then have been stowed on top without further interlayer dunnage in such a manner that they rested tightly against the container walls. The remaining gap in the middle could then have been filled with an airbag or pallet.

5.3.9.2.6 Cartons, mixed cargo, example 6



Packing deficiencies with a high risk of damage

In the event of an extended period of bad weather during maritime transport, the carton (d) could be caused considerable damage by the package (c) or the relatively large wooden case (e). It is essential for the gap between (g) and (h) in the background to be filled and the same applies to the very large gap in front of package (g). Package (f) has been contaminated with liquids, as has package (d).

Packages (a) and (b) ought to have been placed where (d) is located. Gaps could have been filled. Once the surface had been levelled, packages (d) and (e) could have been placed on top. Package (f) ought to have been packed somewhere else.

5.3.9.2.7 Cartons, mixed cargo, example 7

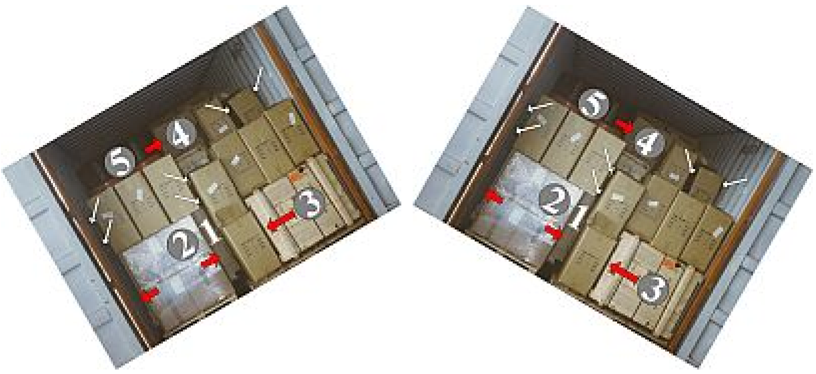
Inadequately packed general purpose container

Careful examination immediately reveals gaps in the stow and other inconsistencies:

Errors in packing the container

Cartons are stowed next to the case visible in the gap (1). The shrink-wrapped cartons (2) can move freely to the left and right. The wooden case (3) can easily start to move to the left. The barrels (5) packed on the stowed wooden case can crush the cartons at (4). Numerous other small gaps (white arrows) complete the dismal picture.

Tilting the picture by 30° reveals the shortcomings even more clearly.



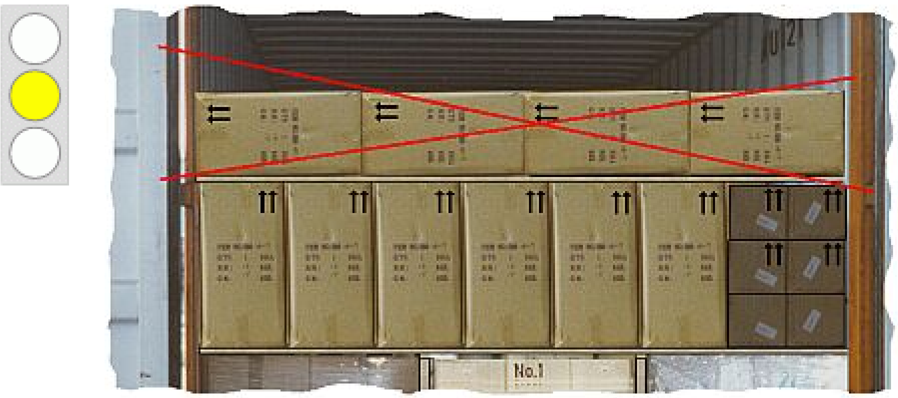
30° tilt of container

It is essential for cases, barrels and other heavy items to be stowed at floor level.

Compact stowage by slight modification of packing

Individual packages can be properly segregated from one another with boards, beams or squared lumber. In this way, individual packages can be prevented from shifting. All light items can be stowed in the upper layers by placing interlayer dunnage.

Packing flexibility is restricted if cargo is marked with handling symbols which specify a particular orientation in the means of transport.

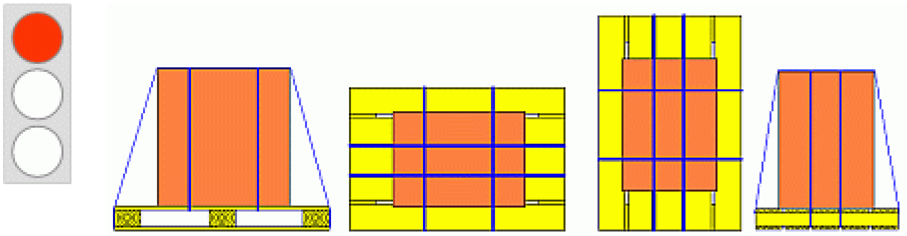


Handling symbols must be observed.

5.3.9.3 Cartons on pallets

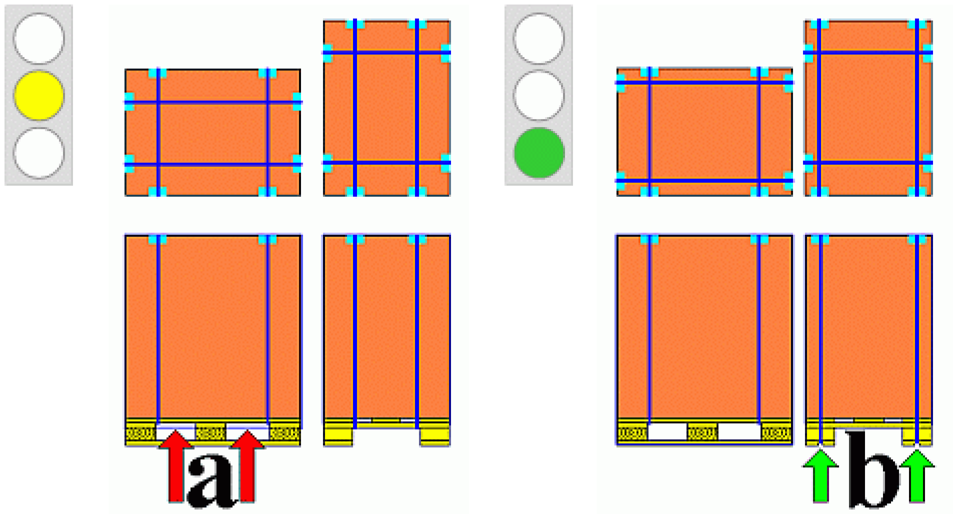
5.3.9.3.1 Cartons on pallets, example 1

Fully palletized cargo simplifies packing in containers carrying mixed consignments. However, when properly secured, the packages illustrated here entail considerable extra labor.



The packages are not "fully" palletized

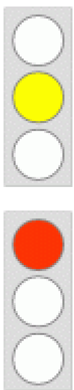
One option is to cut the cartons from the pallet and stow them manually, so entailing extra effort.

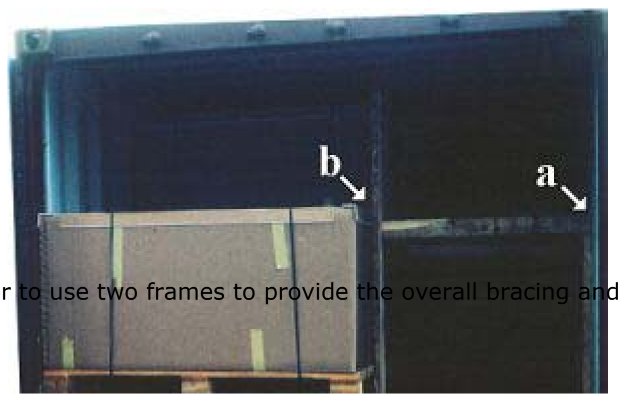


The packages would have been correctly prepared for shipment if they had been packed flush on a stackable base. It is important to ensure that the strapping is not jeopardized by handling with ground conveyors. They could be torn at (a), as this is where the forks are inserted. This cannot happen at (b) because the straps are accommodated in routed grooves.

5.3.9.3.2 Cartons on pallets, example 2

While the simple wooden frame made from two upright boards and squared lumber crosspieces does secure the left-hand pallets and the protects the already damaged cartons, it is still in need of modification. As shown, the upper cross brace is applying a point load on the container side wall (a) and the single board on the pallet (b).

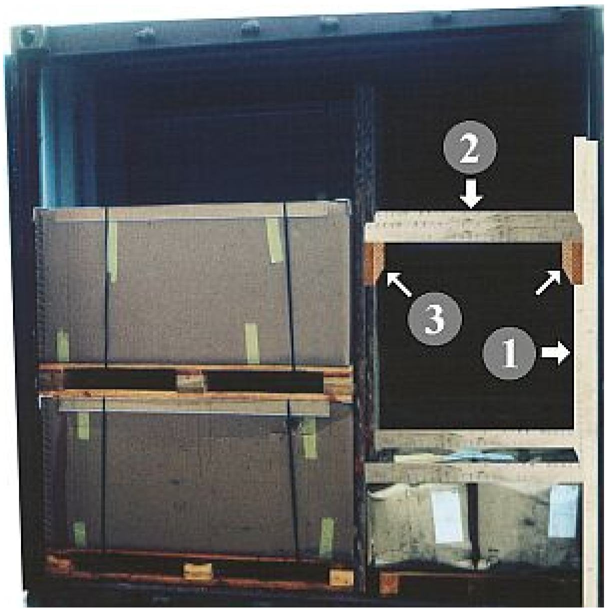




Cartons almost fit for transportation in a container

It is better to use two frames to provide the overall bracing and to modify the structure by choosing taller uprights

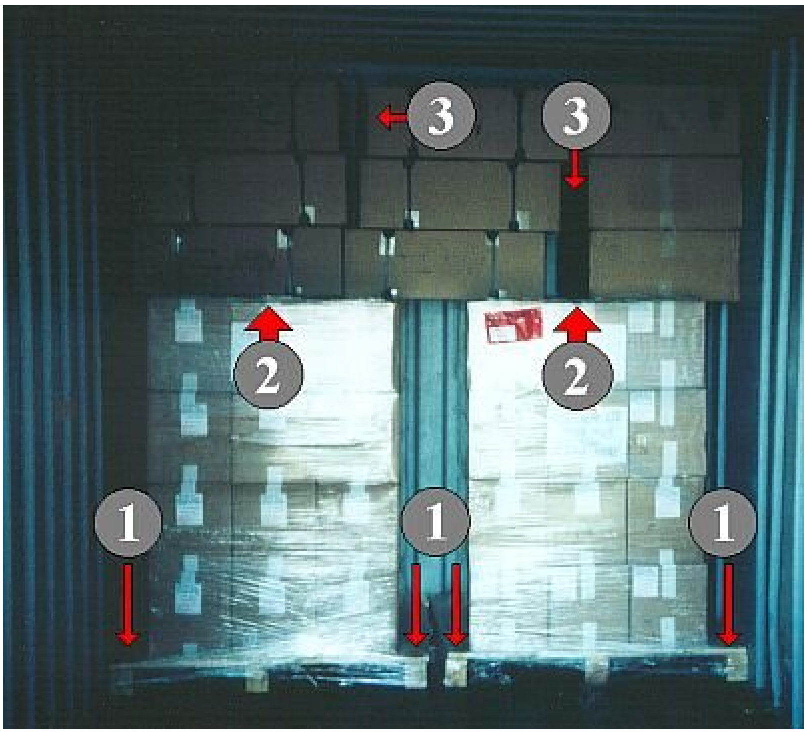
pressure distribution. Wooden members (3) nailed underneath hold the structure together and prevent the upper cross braces from slipping down.



Improved bracing frame

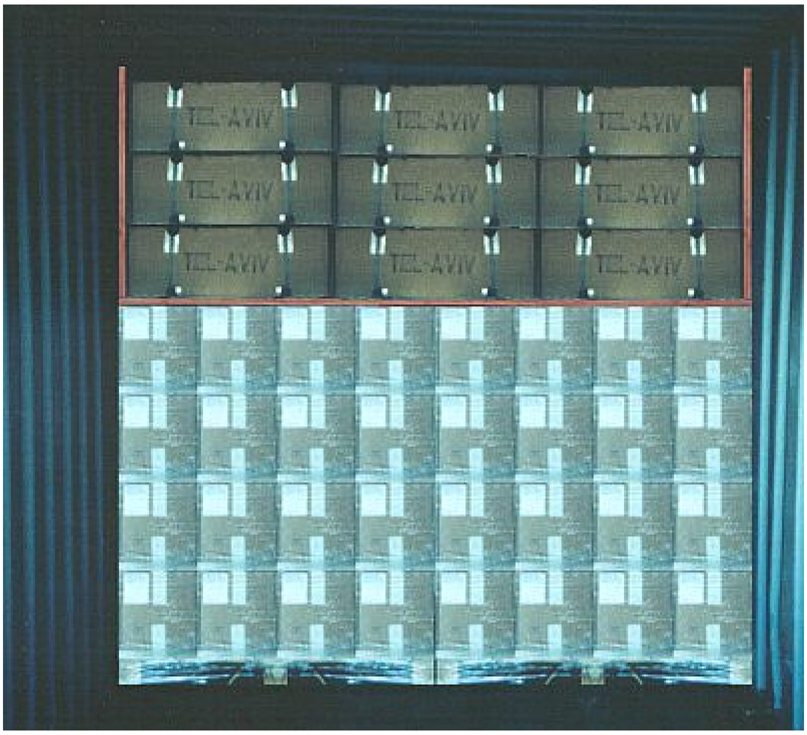
5.3.9.3.3 Cartons on pallets, example 3

The pallets are incorrectly packed and are not fit for container transport. The gaps in the stow (1) may result in damage. There is no interlayer dunnage between the pallets and cartons (2).
Inadequate packing of the cartons has given rise to gaps which promote damage (3).



Poorly packed section in a standard container

This ship en route for Israel has to pass through the North Sea, the English Channel and the Bay of Biscay, all regions which often suffer unfavorable sea conditions. Secure packing could easily have been achieved:



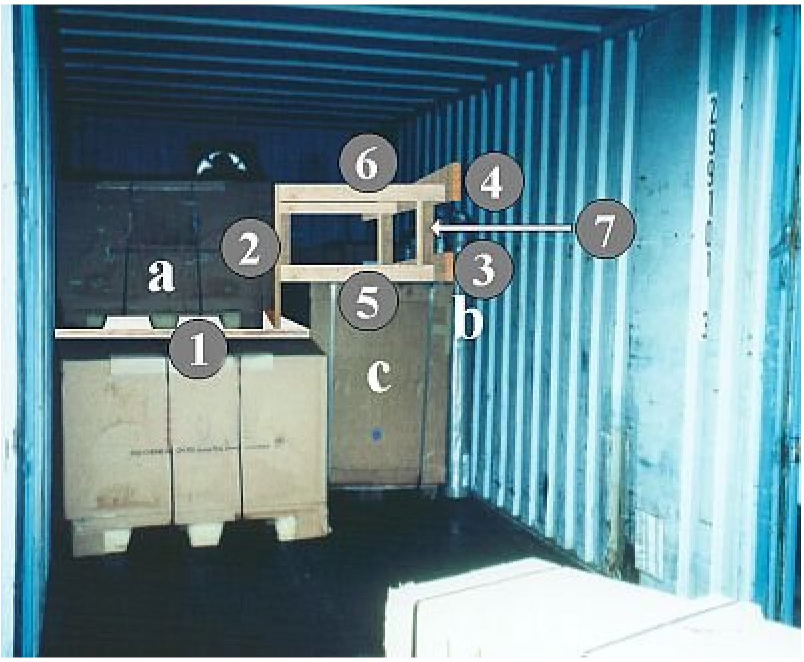
Excellently packed section in a standard container

If the pallets had been made two centimeters wider, they could have been packed flush. Interlayer dunnage made of plywood or chipboard is placed on the pallets, while the same material is used as side dunnage against the container walls. In this way, the cartons fit in the second layer without gaps and would even be protected from sweat from the container sides. If there were any risk of sweat formation, top dunnage of special nonwoven fabric or similar material would have to be laid.

5.3.9.3.4 Cartons on pallets, example 4

Pallet (a) is unsecured. Moreover, its base is exerting an inadmissibly high pressure on the package stowed beneath.

General cargo in a ventilated container



Bracing package (a)

Sheets or boards (1) should be laid under the package (a) to distribute the pressure. Boards or the like should likewise be placed to the side of package (2), the upright rolls (3) and the container wall (4) in order to distribute pressure. Wooden crosspieces (5) and (6) brace the sideways loads. The uprights (7) stabilize the structure.

.3.9.3.5 Cartons on pallets, example 5

Container packing deficiencies due to gaps and goods at risk of tipping

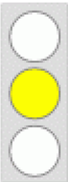
The various cargo dimensions, some of which are not suitable for container packing, mean that gaps are left which absolutely must be filled. This is particularly important for goods or pallets which are at risk of tipping and which are packed in layers without adequate shrink or other wrapping.

Gaps must always be filled in. If necessary, interlayer dunnage should be laid.

The gaps in the floor layer are more obvious from this perspective and something must be done about them. If a second layer of cargo is to be stowed, interlayer dunnage of wood or comparable materials must be laid.

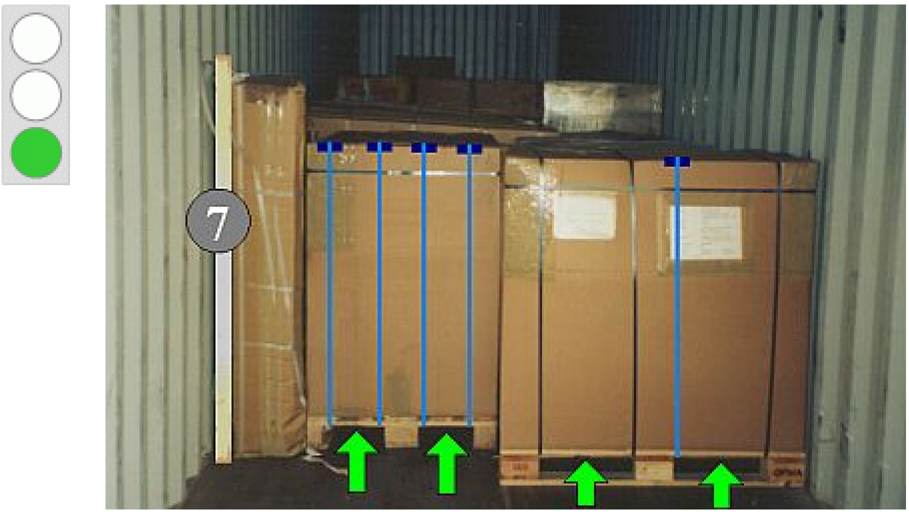
5.3.9.3.6 Cartons on pallets, example 6

Another example of packing deficiencies.



Slight packing deficiencies in a general purpose container

The packaging of package (1) is too weak or has already been slightly damaged by handling. Even the slight gaps between packages (1) and (2) and between (2) and (3) could result in damage. Poor application of the straps (4) and (5) on package (2) could result in the straps bursting on lifting with a forklift truck, so leaving the carton standing unsecured on the pallet. A somewhat better solution has been found for package (3), but strapping is missing at (6). A negative feature is that steel strapping has been used without adequate edge protection.



Packing improved by slight modifications

A satisfactory result can be achieved just by pushing the packages closer together and filling the resultant gap at (7).

Sometimes the details make all the difference.

Inadequate support under a pallet

Usable support under a pallet

Supporting the pallet (1) with a vertical squared lumber member is not satisfactory in this case. There is nothing to ensure that this member will stay in place during a voyage. The wooden structure (2) is a usable solution, but, although it will stay in place, considerable labor and thus costs are involved.

Gap left in the stow

Bracing a gap

The large gap between the package (3) and container side wall absolutely must be braced. A feasible structure of squared lumber and boards is shown here (4). However, it is always better to ensure that container-compatible dimensions and stowage methods are used throughout packaging, palletization and stowage.

5.3.9.3.7 Cartons on pallets, example 7

Every shipowner endeavors to minimize the number of empty containers which are carried. Refrigerated containers, which are required at a destination to carry temperature-controlled cargo, are thus often used on the outward voyage as standard box containers for general cargo.

Inadequately secured cargo in a refrigerated container

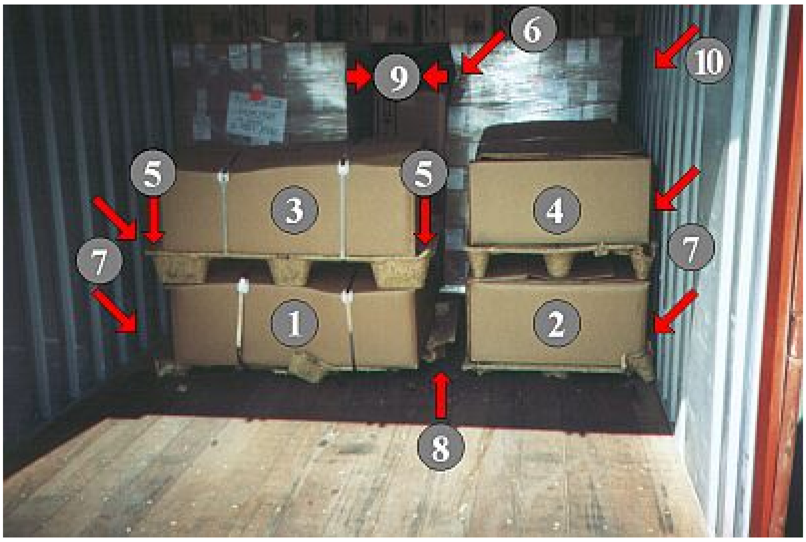
An only partially successful attempt has been made to achieve a compact stow by using airbags. There is a risk that the packaging around the packages will collapse, damaging the contents, because, due to the way in which the airbags are used, point loads are being applied.

Correct use of airbag

If airbags are used to fill gaps between insufficiently resistant packages, boards or sheets of chipboard or plywood or equivalent materials should be placed between the airbag and cargo. The airbags themselves should be of dimensions such that they apply pressure over a large area.

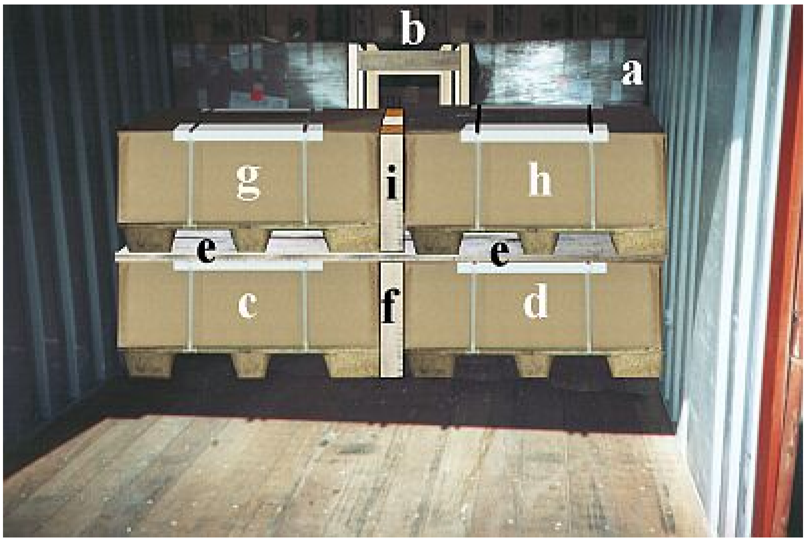
Of course, in the example shown, further cargo must be compactly stowed or the remaining gaps around the left-hand pallet and towards the door must be filled with bracing.

5.3.9.3.8 Cartons on pallets, example 8



Damage is inevitable with packaging and stowage like this.

As can easily be seen, the chipboard pallets of packages (1) and (2) have already been severely damaged or completely destroyed before or during container packing. It is clear at (3) and (4) that the pallets do not match the dimensions of the cartons strapped onto them, they extend beyond the edge of the cartons. This is even more clearly visible at (5). The cartons themselves have not been made sufficiently strong for their contents. The strapping has also been applied without sufficient edge protection. The cartons on the wrapped pallets are also very weak. This is clearly visible at (6). Clear violations of the basic rules of packing are present at (7), (8), (9) and (10).



Better packing options

Cargo transport risks could have been mitigated in this way.

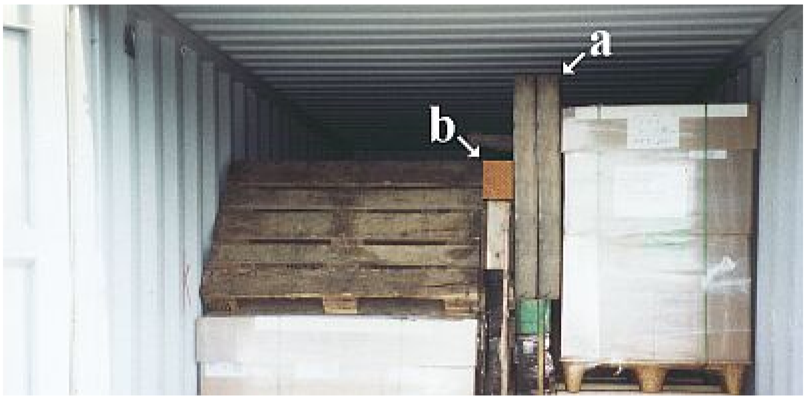
The gap at (10) is eliminated by placing the wrapped pallet tightly against the container wall at a. The gap b is braced by means of squared lumber uprights or wooden lattices plus wooden crosspieces. The cartons c, d, g and h are strapped on correctly dimensioned chipboard pallets with sufficiently strong edge protection. The new pallet dimensions mean that now in each case two of them fit crosswise into the container, whereas previously the cartons d (prev. 2) and h (prev. 4) were introduced lengthwise. The slight gap between the cartons or pallets c and d placed flush to the left and right against the container walls is filled with the squared lumber f, with large area dunnage e consisting of boards or slabs being positioned on top. Then the cartons or pallets g and h are loaded and the remaining gap I filled with squared lumber.

5.3.9.3.9 Cartons on pallets, example 9

The following shortcoming may not look very dramatic, but can still result in cargo damage.

Small cause, big effect

Package (1) can topple and be damaged because the gap in the stow has not been completely filled.



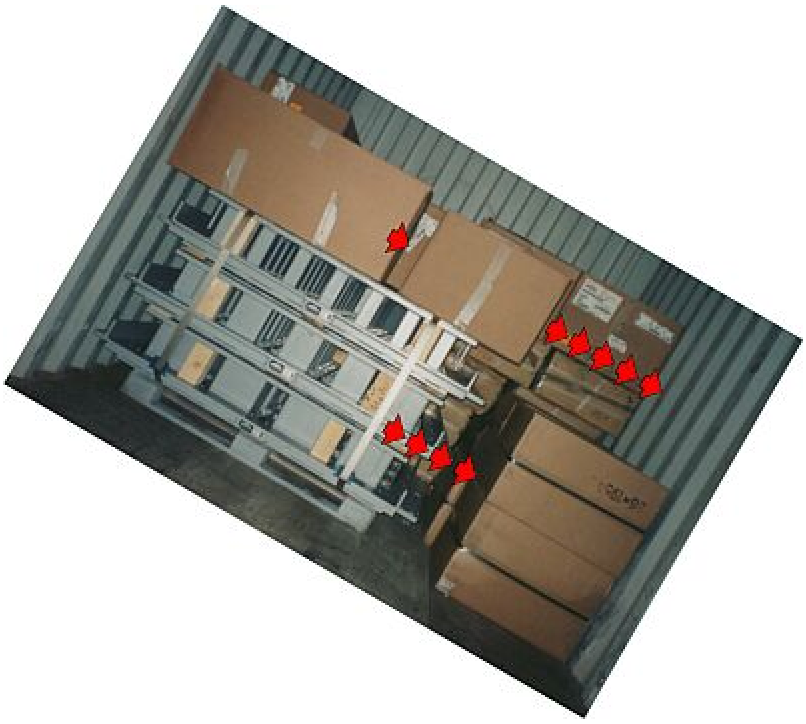
An additional pallet, a, and a squared lumber member, b, provide a compact stow. In general, however, using so many spare pallets for cargo securing merits criticism. As already mentioned, this may result in additional disposal costs in some receiving countries.

5.3.10 Steel and metal products, mixed cargo

5.3.10.1 Steel and metal products, mixed cargo, example 1

Inadequate packing increases the risk to which the goods are exposed.

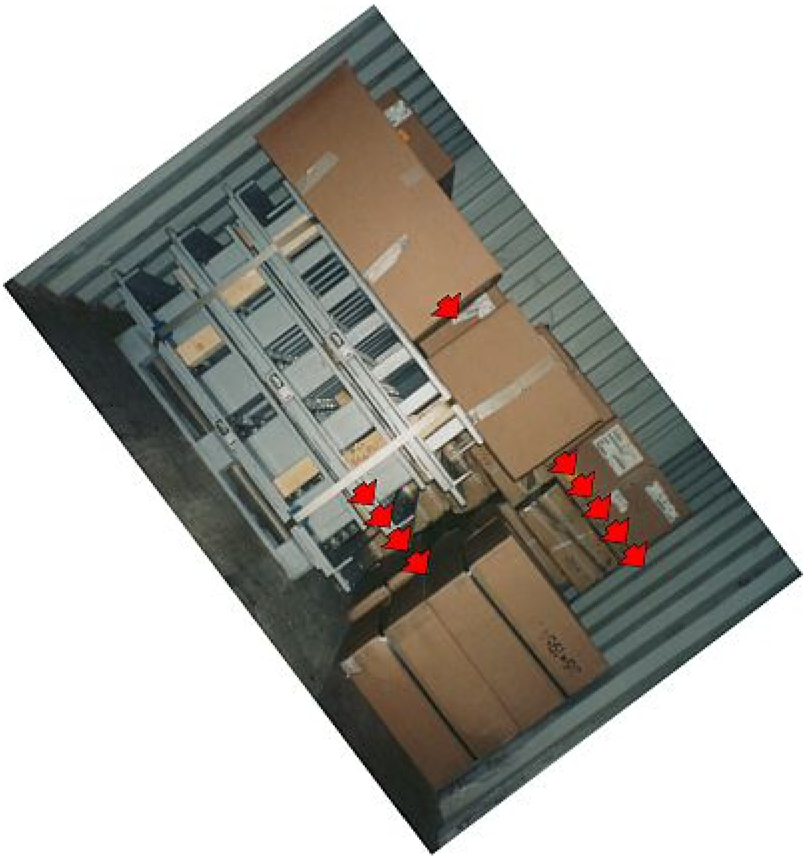
The fact that there is a potential for cargo damage becomes particularly clear if the container is tilted to an angle of 30°.



... An angle of 30° is enough to get a good part of the cargo sliding ...

This angle corresponds to rolling angles which are to be anticipated in overseas transport or the sideways acceleration forces of 0.5 g to be expected in road and rail transport.

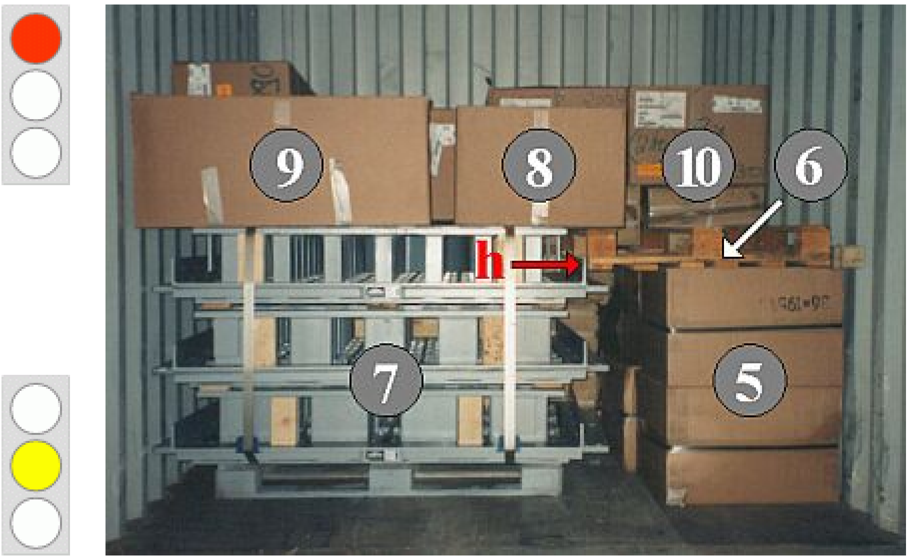
The consequences of inadequate stowage and securing are even clearer if acceleration forces of 0.8 g are presented as a tilt angle of 53°.



... At an angle of 53°, almost everything will slide ...

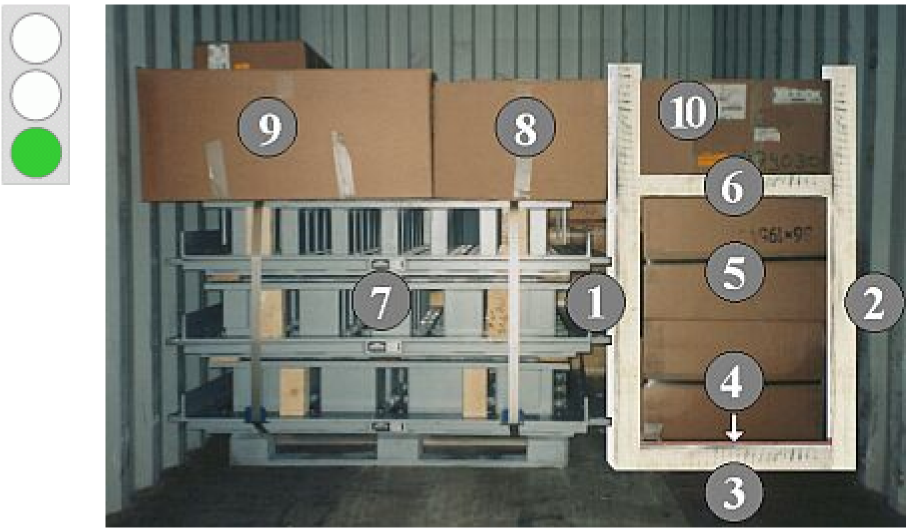
How much of the cartoned goods, truck parts and container will still be usable?

It will take more than putting a pallet on top to remedy the securing deficiencies:



Laying a pallet (6) on top of the cartons (5) is not a satisfactory solution. While the inertia forces generated by the bundled truck parts (7) will be transferred from the point (h) indicated with the red arrow via the pallet to the right-hand container wall, the result will be a point load over a very small effective height against a few container corrugations. The issue of the gaps in the stow between (5) and (7), (8) and (9) and (8) and the right-hand container wall remains unresolved and these gaps absolutely must be eliminated.

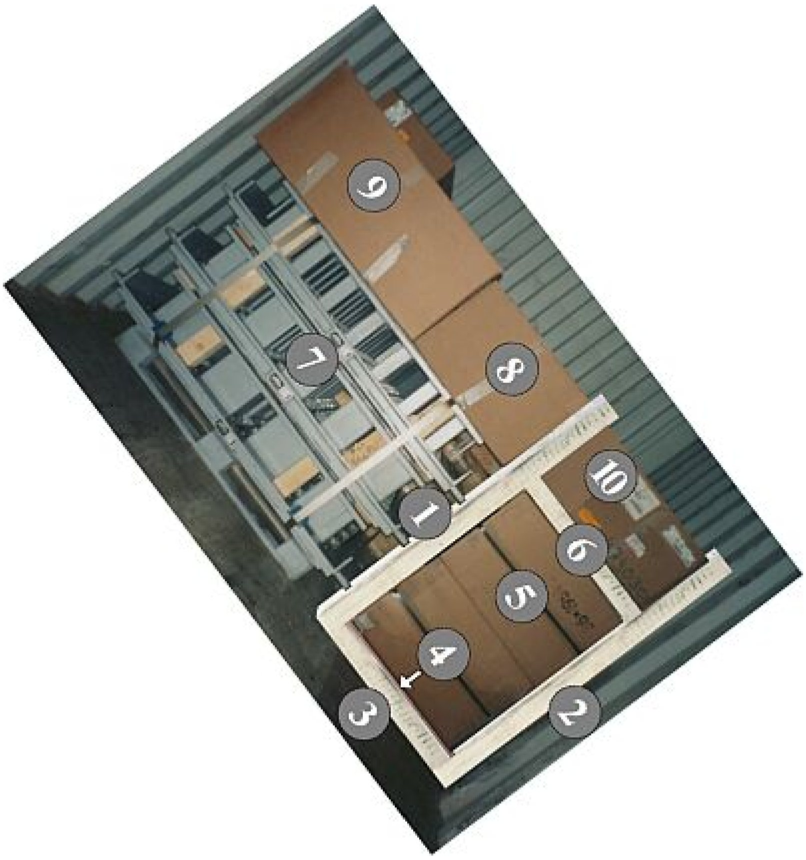
Reasonable securing is not very difficult to achieve:



Proposed securing method for truck parts and cartons

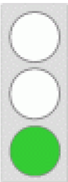
Two u-shaped frames are constructed from two approx. 1.70 m tall squared lumber uprights (1) and (2) together with two cross braces (3), the frames being connected together at floor level with a narrow plywood sheet or wooden dunnage boards (4) laid lengthwise, on which the carton (5) is stowed. The upper parts of the two squared lumber uprights (1) and (2) are braced with two crosspieces (6). The heavy package (7) and the lighter packages (8) and (9) can lean against this structure. Package (10) and other small parts can be stowed "without pressure" and thus protected in the gap between the members (6).

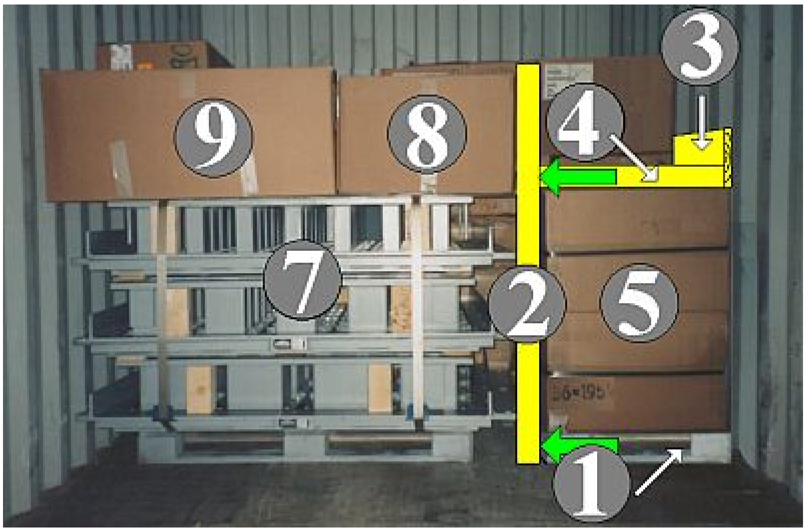
Securing in this manner will even withstand acceleration forces of 0.8 g. There is no risk of cargo damage.



Simulation of 0.8 g acceleration by tilting

Another variant:





Alternative securing method for packing truck parts and cartons

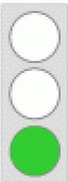
The packages (5) are placed on a pallet and stowed tightly against the right-hand container wall. The gap between the cartons (5) and truck parts (7) is filled with two squared lumber uprights (2) which extend sufficiently far upwards also to be able to prevent packages (8) and (9) from moving sideways. The gap above the cartons (5) is braced with a board (3) laid lengthwise against the container side wall to distribute the pressure and two squared lumber members (4).

5.3.10.2 Steel and metal products, mixed cargo, example 2

Plant parts in a 20' container
- unsecured in transverse direction

Before further cargo can be stowed, the gaps must be eliminated.

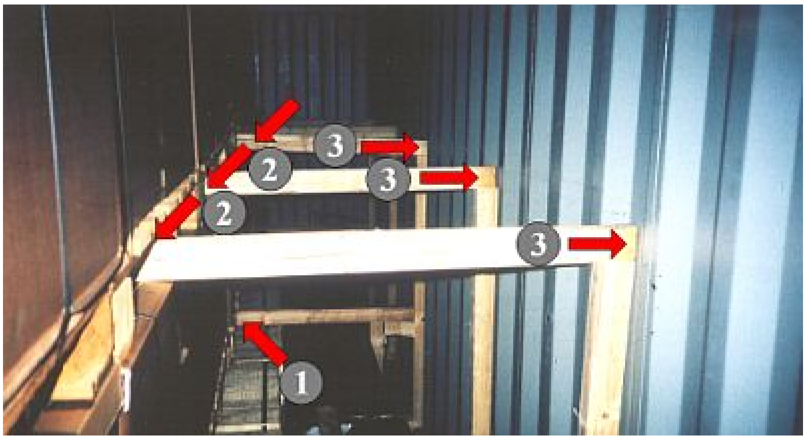
The gaps present must at least be filled with suitable squared lumber members, which should be fastened in place.



Plant parts in a 20' container
- gap braced in transverse direction

If a flat loading surface is required, the right-hand package can be raised on supports. Packing must be continued in accordance with the stated rules.

5.3.10.3 Steel and metal products, mixed cargo, example 3

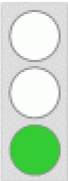


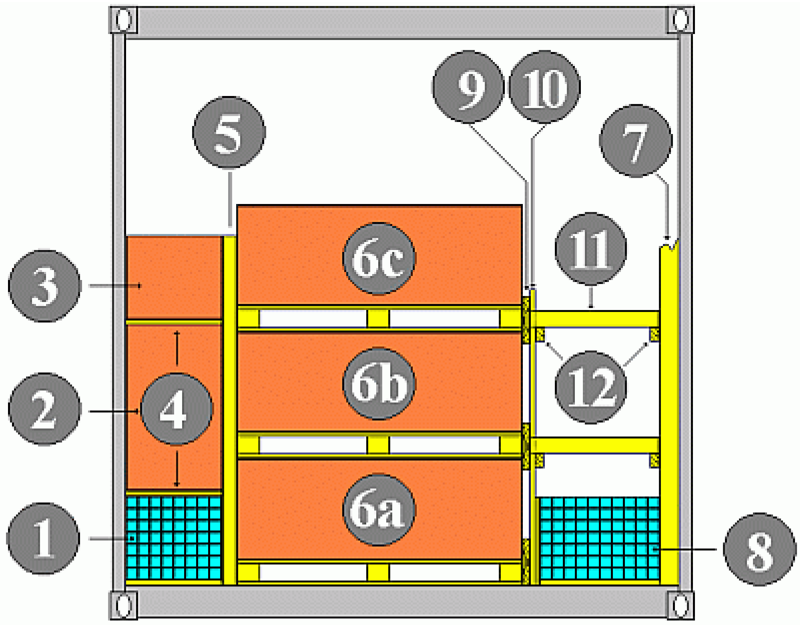
Inadequate "securing" with squared lumber members

An utter waste of materials. Just what is this "securing" intended to achieve? The wooden members (1) and (2) have just been inserted in the pallet-like package bases and fastened in place with nails.

The wooden members are exposing the container side wall to point loads at the ends (3) because the crosspieces are resting on the uprights.

Depending on the mass and nature of the cargo, appropriate securing might have looked like this:





Proper securing

The steel profiles (1) are stowed tightly to the left-hand container wall. Packages (2) and (3) are stacked on top of the profiles using interlayer dunnage (4) in the form of beams, boards or sheets. Squared lumber uprights (5) are placed in an appropriate number against this cargo and packages (6a), (6b) and (6c) are packed against these uprights. Squared lumber uprights (7) are set against the right-hand container side wall, the height of the uprights being determined by the forces to be absorbed. If severe stresses are anticipated, they are taken up to the container's top side rail. A lattice of boards (9) and (10) is fabricated (outside the container) and inserted into the gap between packages (6) and (8). The large space between the lattice and squared lumber uprights (7) is filled with cross braces (11). Lengthwise, nailed battens (12) or boards increase the stability of the bracing.

5.3.11 General cargo in open-top containers

Example 1

Unsecured general cargo in a 20' open-top container

If this container is carried by sea in this state, damage is inevitable.

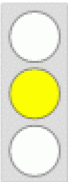
Example 2

Packing a 20' hard-top open-top container

A positive feature is that a secure cargo end face towards the doors is being constructed. Setting down the larger packages in the door area saves considerable labor. In the front part, the dimensions of the packages are such that some gaps are produced. These were filled in with smaller items of cargo, wooden members, old pallets etc. in such a manner that, overall, a compact stow was achieved. There is no risk of damage to individual items of cargo.

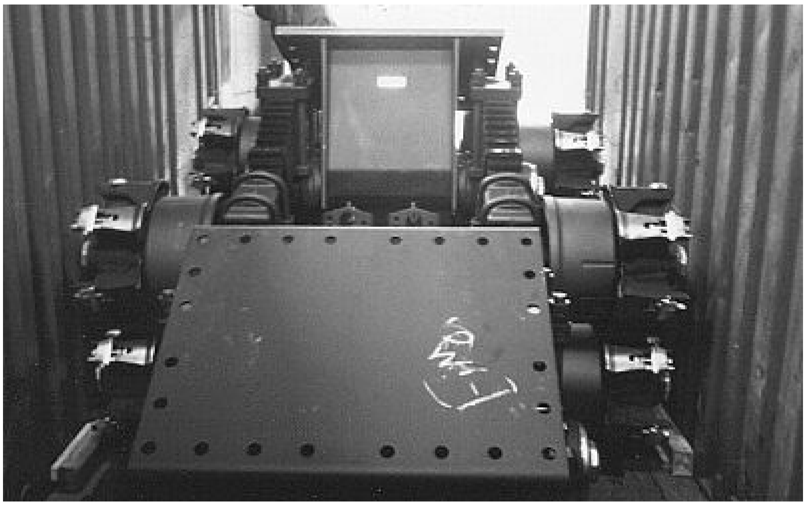
Final work on a 20' hard-top open-top container

Example 3



Packing the first truck axles in the container

In the foreground of the picture, there is a roll of friction-enhancing material, which has a very high coefficient of sliding friction and is laid between layers. This thin material is not suitable for laying under cargo. Strips of friction-enhancing (FE) mats at least 10 mm in thickness are necessary under the lower layer of axles.



Upper part of unsecured stack of truck axles

Some wooden members used to fix the lower layers are visible underneath. In the upper layers, the friction-enhancing material laid between the layers is expected to provide sufficient stability. This otherwise inadequately secured stack will not withstand extended exposure to bad weather at sea.

Packing the axles centrally, as shown, is unfavorable for securing as the gaps left on both sides must be filled. Alternatively, the entire cargo block could be lashed.

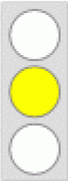
One efficient securing method is to leave gaps towards the container side walls alternately to the left and to the right. In this way, only one gap need be filled in each case.

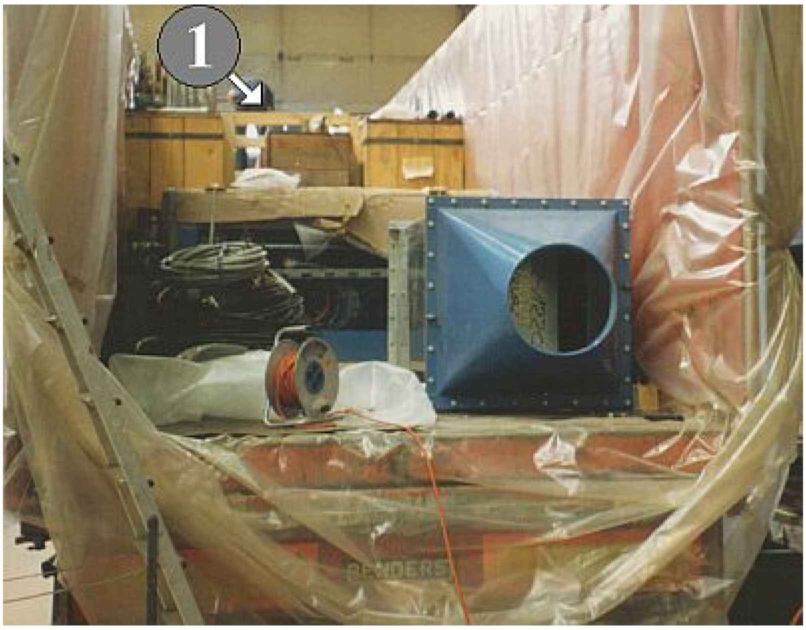
The sensitive axle heads must be protected. They are in each case packed tightly against the container wall on one side, while the gaps left on the other side must be filled with lumber, airbags or the like.

Example 4: Plant parts in a 20' open-top container

In order to provide the plant parts with protection from climatic conditions, the entire container is being lined with 200 μm gage polypropylene film. 200 μm corresponds to a thickness of 0.2 mm.

Lining a container with polypropylene (PP) film





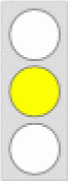
View into the partially packed container

The two wooden cases in the front part of the container are secured with wooden cross bracing. The vertical wooden members could have been dispensed with if wooden members fastened under a board had been suspended in the gap from above.

Wooden securing member which can be suspended between case lids

The problem with the planned measures to provide protection from climatic conditions is that desiccant would have to be placed inside the as yet unsealed PP package in quantities sufficient to absorb not only the moisture present in the package but also any water vapor which diffuses in through the film. Lumber, such as the case sides and wooden securing members, normally contains a very large amount of moisture, unless kiln dry lumber is used. The same applies to other packaging containers and packaging aids such as cardboard, paper etc. It is not very likely that the necessary quantity of desiccant will be calculated correctly and actually placed inside the package. The manner in which the other items of cargo have been arranged in the rear part of the container would lead one to suspect that the cargo will not be sufficiently tightly packed.

Heat sealing the protective film



Packing operations in an open-top container

This confirms the suspicion - the cargo is not sufficiently tightly packed and secured.

The container could only be considered to be packed in a manner fit for transport once the gaps still present have been completely filled and the heavy parts separately secured.

5.3.12 Kitchens in standard containers

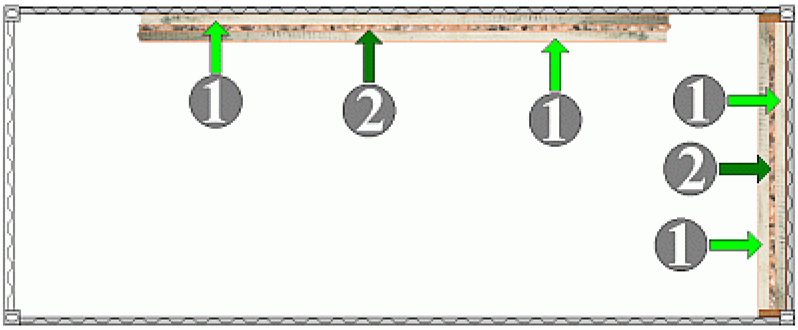
Careless packing in the container considerably increases transport risks. Damage is inevitable if the ships carrying the containers encounter severe weather.

Careless packing of kitchens and kitchen accessories

Reference is made in connection with this photograph to the "General notes on packing box containers", "General cargo in box containers" and "Basic stowage methods". Packing without gaps is intended to deprive packages of the ability to move even slightly during container transport. Deciding how to pack fragile components, such as granite work surfaces or kitchen units with glass panels, is not simple. Such components are best packed lengthwise and on edge for road and rail transport and for athwartships stowage of the container on board ship. For standard transport on board ship in fore and aft stowage, they should preferably be packed crosswise and on edge.

This latter variant is only feasible for relatively short components whose length does not exceed the width or height of the container. Longer work surfaces inevitably have to packed lengthwise and on edge.

The work surfaces must be packed so compactly that they have absolutely no freedom of movement. Cushioning materials must not be used as the continual motion of the ship and the consequent compaction of the material will create space for the cargo to move about in, so greatly promoting the risk of damage.



Rigid packing of granite slabs

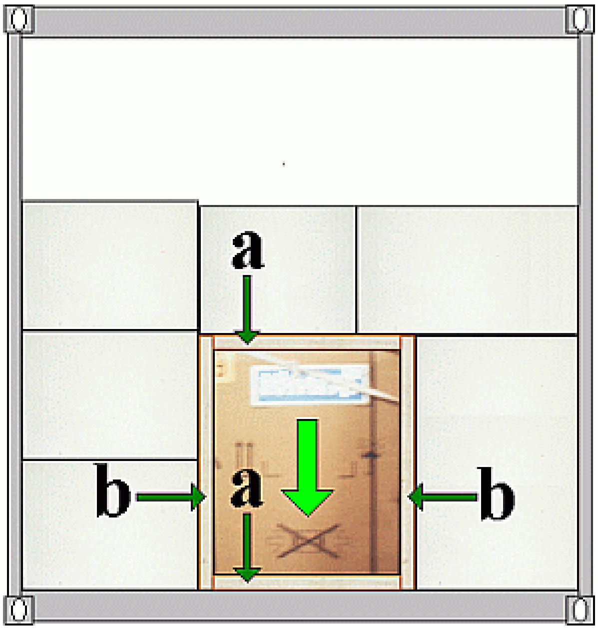
Sufficiently rigid wooden members (1) protect the vertically packed granite slabs (2) from breakage. Another packing option is to use A-frames.

Granite slabs on A-frames

The granite slabs must be secured on the A-frames with a sufficient quantity of strapping. The frames themselves must either be blocked, lashed or stowed so compactly by other items of cargo that they are prevented from moving at all in the container.

Incorrect packing of electrical goods

Any packages containing electrical items must be packed in such a way that they are not exposed to harmful pressure: It is essential to comply with any printed handling symbols, in this case: protect from lateral stresses. If required, the items of cargo must be protected with inserted bracing.



Protecting a pressure-sensitive package with wooden bracing

Lateral forces are kept away from the sensitive package by means of horizontal wooden members (a) in conjunction with wooden uprights (b).

Negligent and careless packing increases the risk of damage.

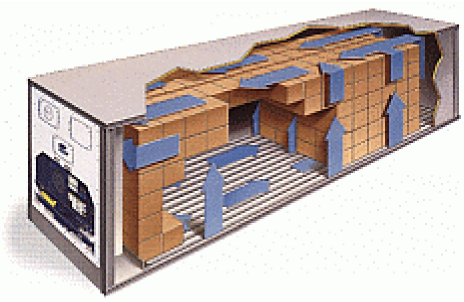
Consistently neat and tidy packing is an essential prerequisite. Damage is inevitable when cargo is packed as shown. "Securing" the packages in the door area with webbing belts is useless. If an interlocked stow cannot be created, wooden lattices or similarly effective methods must be used to provide a secure cargo end face.

Inadequate stowage and securing of kitchen furniture in a container

Depending on the destination, care may have to taken to ensure that cardboard packaging and the steel container walls do not come into direct contact. If cardboard packaging containers come into contact with condensation, they will soften and the contents will be damaged. In this case too, the negligent packing and inadequate cargo securing merit the severest criticism.

Dr. Yves Wild

Refrigerated containers and CA technology



6 Trends in maritime refrigerated transport

Following a sharp downturn at the beginning of the 1980s, the volume of refrigerated products transported by sea has continued to see steady growth. The following tables show the volume of goods transported by sea. Please note that there may be minor discrepancies between the various sources.

The primary refrigerated products are bananas, meat, citrus fruit, fish and seasonal fruit. Developments over the last fifteen years with regard to these various refrigerated goods can be seen from the tables. The highest growth in absolute terms is in bananas and meat, which have a large share of the overall market anyway.

The proportion of the respective products transported by sea compared with the total volume transported varies considerably: Bananas are almost always transported by sea (99%), whereas the proportion for citrus fruit is only 52%, for seasonal fruit 48% and for dairy products 41%.

Trends in the maritime transport of refrigerated products
Source: Ocean Shipping Consultants 1994

	Bananas	Meat	Citrus	Seasonal fruit	Fish	Dairy products	Other	**Total**	Annual increase
1981	6.78	6.24	5.99	2.23	1.75	1.05	0.15	**24.19**	-
1982	6.77	6.13	6.13	2.14	1.82	1.04	0.20	**24.23**	0.2%
1983	6.07	6.25	6.10	2.45	1.95	0.89	0.21	**23.92**	-1.3%
1984	6.59	5.96	6.14	2.28	2.15	1.01	0.32	**24.45**	2.2%
1985	7.13	6.07	5.76	2.46	2.72	1.05	0.35	**25.54**	4.5%
1986	7.26	6.45	6.27	2.32	2.95	1.10	0.28	**26.63**	4.3%
1987	7.51	6.68	6.50	2.56	3.41	0.95	0.35	**27.96**	5.0%
1988	7.84	7.21	6.80	2.73	3.95	0.95	0.54	**30.02**	7.4%
1989	8.28	7.50	7.05	2.89	4.05	0.95	0.65	**31.37**	4.5%
1990	9.04	7.75	6.88	3.00	4.10	1.05	0.72	**32.54**	3.7%
1991	9.93	8.31	6.79	3.21	4.45	1.12	0.85	**34.66**	6.5%
1992	10.45	8.47	7.14	3.32	4.95	1.16	0.95	**36.44**	5.1%
1993	10.44	8.45	7.08	3.37	5.20	1.10	1.05	**36.69**	0.7%
1994	10.85	8.92	7.34	3.50	5.35	1.21	1.15	**38.32**	4.4%
1995	11.31	9.63	7.61	3.67	5.45	1.38	1.20	**40.25**	5.0%
1996	11.66	10.30	7.82	3.87	5.50	1.42	1.25	**41.82**	3.9%
1997	12.02	11.13	8.13	4.05	5.50	1.50	1.38	**43.71**	4.5%
1998	12.44	12.02	8.42	4.25	5.65	1.56	1.45	**45.79**	4.8%
1999	13.02	12.98	8.59	4.37	5.75	1.72	1.51	**47.94**	4.7%
2000	13.69	14.02	8.78	4.53	6.00	1.95	1.60	**50.57**	5.5%

All values are in million metric tons
Post 1993, values are estimated

Table 1: Trends in the overall volume of refrigerated products transported by sea [1]

Trends in the maritime transport of refrigerated products
Source: Drewry Shipping Consultants 1999

	Bananas	Meat	Citrus	Seasonal fruit	Exotic fruit	Fish	Dairy products	Other	**Total**
1985	7.02	4.80	4.25	2.17	-	2.20	1.60	-	**22.04**
1986	13.33	9.71	4.58	3.99	1.35	8.77	1.56	4.12	**47.41**
2000	14.12	10.76	4.99	4.32	1.54	9.18	1.59	4.93	**51.43**
2005	15.80	12.28	5.33	4.71	1.76	9.74	1.65	5.84	**57.11**

All values in million metric tons
Figures as of 2000 are estimates

Seasonal fruit:	Apples, pears, dessert grapes
Exotic fruits:	Pineapples, kiwi fruit, avocados
Fish:	Fresh, chilled and frozen
Dairy products:	Butter and cheese

Table 2: Trends in the overall volume of refrigerated products transported by sea [2]

Figure 1 shows the various refrigerated goods as proportions of the overall volume in 1996. The typical frozen goods, i.e. meat, fish and dairy products, constitute around 42% of the overall volume, and fruit transport constitutes around 56%.

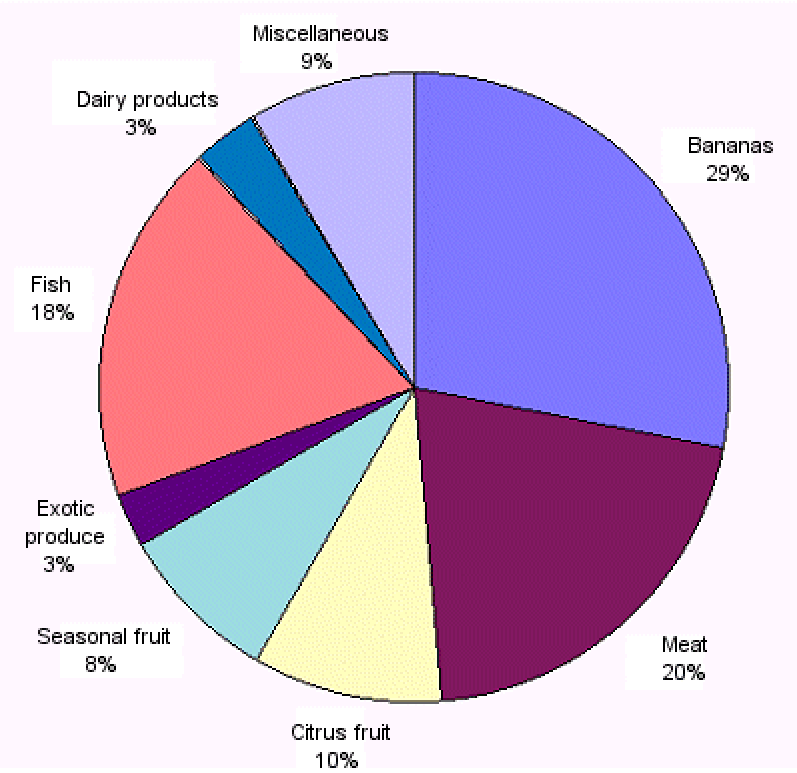


Figure 1: Proportions of the various refrigerated products transported by sea [2]

The main countries of origin of refrigerated products that are imported into the EU are shown in Figure 2: This also reflects the importance of fruit transport, since countries such as Costa Rica, South Africa, Ecuador, Colombia and Morocco are primarily fruit suppliers.

Large volumes of refrigerated goods are still transported on refrigerated cargo ships, as is the case for bananas in particular. Modern refrigerated cargo ships are also providing ever increasing capacity for transporting refrigerated containers (reefers) on deck (up to approx. 120 FEU = 240 TEU).

But there is also a clear trend towards increased containerization, which means that refrigerated cargo ships are increasingly facing competition from reefers. Thus, very few refrigerated container ships are built today, and transport capacities for reefers is growing significantly faster than the refrigerated goods market (see Section 2.2.2). Today, the

reefer market is largely dominated by reefers with integrated refrigeration units.

The proportion of reefers used for maritime transport of refrigerated goods was around 50% in 2000. This of course varies depending on the cargo type.

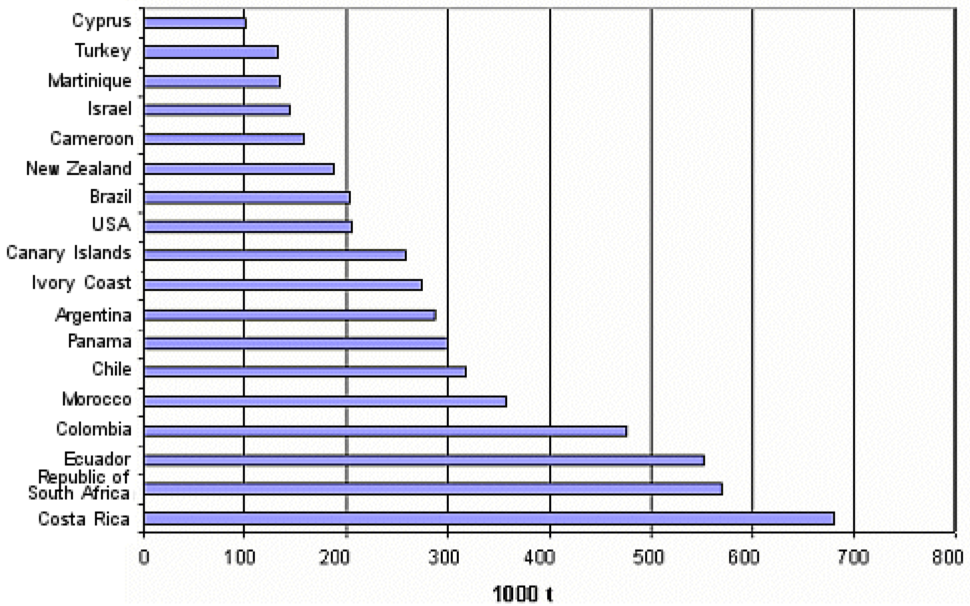


Figure 2: Imports of fresh fruit into the EU by country of origin 1994 [3]

7 Refrigerated containers

There are two basic types of refrigerated container (reefer) which have each developed differently over the course of time:

- Porthole refrigerated containers, also called insulated or Conair containers, do not have their own refrigeration unit. They are thus reliant on an external supply of cold air. Refrigeration units of various types, permanently installed on the ship, permanently installed in the terminal or clip-on units for individual

containers, are used for this. (see below)

- Integral refrigerated containers, on the other hand, have an integrated refrigeration unit, which is generally powered nowadays using a 3-phase electric power supply.

Nearly all statistics on containers refer to the "TEU" unit. TEU stands for "Twenty foot Equivalent Unit" and is used to designate a 20' container. A 40' container thus comprises 2 TEUs. Sometimes the unit "FEU" is used for 40' containers. 1 FEU is therefore equivalent to 2 TEUs.

7.1 Porthole refrigerated containers

Porthole container technology was developed before the seventies and used on the North-South routes which carried large volumes of refrigerated cargo. The first generation of container ships with porthole refrigerated containers is now over twenty-five years old and will soon be replaced by ships with a greater capacity for integral refrigerated containers.

Porthole containers are thermally insulated and have two sealable openings on the end walls (the portholes) through which cold air can be blown into the container and warm air can be extracted. The cold air is forced through the lower aperture into the container, then distributed throughout the load via a T-bar grating and subsequently flows through the load to the top of the container and is extracted through the upper aperture.

Porthole containers are available in three sizes, each for different regions: 8' high, 20' containers used by operators in Australia, New Zealand and South America when transporting goods to Europe, 8½' high, 20' containers between South Africa and Europe, and 8½' high, 40' containers between the west coast of South America / the Caribbean and Europe.

Since porthole containers do not have an integrated refrigeration unit, they always need to be refrigerated by external means. This can be achieved in various different ways, depending on the current location of the container.

7.1.1 Cold air supply on ships

Special porthole container ships are equipped with refrigeration units permanently installed below deck which supply the containers with the cold air they require. Originally, individual refrigeration ducts were used to supply cold air to up to 48 refrigerated containers and were arranged horizontally and vertically. Subsequently, only a vertical arrangement was used. This was better suited to on-board handling, enabling a clear division of containers and temperatures and producing smaller batches of cargo.

Figure 3 illustrates the principle used in refrigerating porthole containers. In cooling systems permanently installed on the ship, heat is dissipated from the porthole containers via fixed ducts in the cooling system. The vertical cooling ducts are divided into two channels (supply air duct and return air duct). The supply air duct is connected to the lower aperture in the end wall of the container via switchable couplings. The cold air flows through this duct into the container below the grating, through the cargo and then back over the cargo through the upper opening via the coupling to the return air duct. The heated air is drawn off from the return air channel by the refrigeration duct fan and then conveyed back into the supply air channel by the fan.

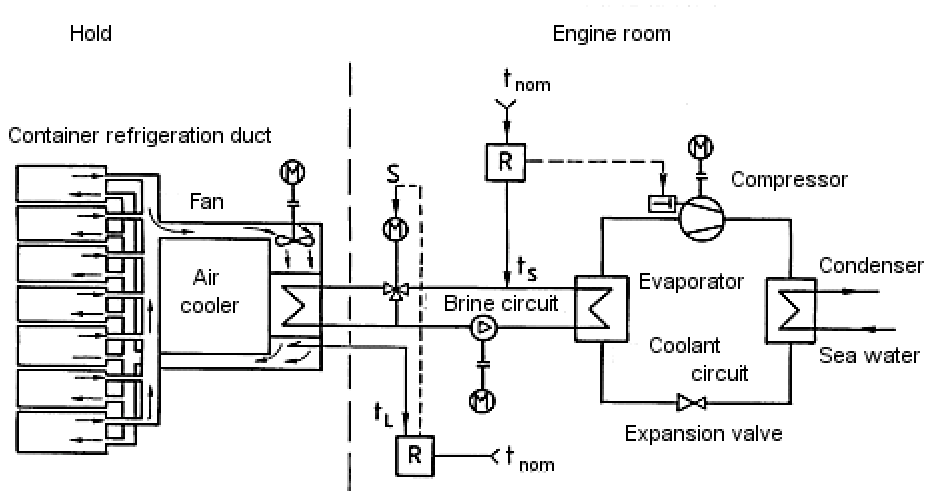


Figure 3: Schematic representation of a porthole cargo refrigeration plant comprising the cooling system, the brine system and cold air system

Figure 3 shows an indirect system with an intermediate brine circuit which connects the cooling system which is located centrally in the engine room to the cold air system in the hold. The supply air temperature is here controlled by adjusting the three-way valve in the brine circuit. Since the installed refrigeration units are relatively large, porthole containers may thus achieve a higher level of efficiency than integral containers. The average power consumption for cooling a TEU, including all auxiliary units, is between approximately 1.5 kW (direct refrigeration plant) and approximately 2.5 kW (indirect refrigeration plant). By comparison: An integral refrigerated container requires on average approximately 3.6 kW per TEU, and between 4.2 kW and 5 kW for transport below deck with additional air cooling (see also Section 8.1.2). Average power consumption, however, depends primarily on the cargo mix and thus on the transport route.

Figure 4: Permanently installed refrigeration system supplying cold air to porthole containers on board MS Allianca Brasil

Figure 4 shows the arrangement of the refrigeration ducts with the couplings in the hold of a container ship on which up to seven refrigerated containers can be stacked and connected to a single refrigeration duct.

Sometimes, porthole containers are also transported on deck. If this is done, a "clip-on unit" is attached to the container which supplies it with cold air. Clip-on units are also used to refrigerate the containers at terminals or when transporting them by truck (see Figure 5). They require a 3-phase power supply to operate.

Figure 5: Clip-on for transport by truck;
photo: K.-H. Hochhaus

7.1.2 Cold air supply at terminals

To refrigerate porthole containers at terminals, a number of mobile or fixed refrigeration units are available in addition to the clip-ons described previously. Each of the tower units shown in Figure 7 can refrigerate two porthole containers, one positioned on each side of the unit. Several of these units can be stacked one on top of the other, allowing tiered stowage. Figure 6, on the other hand, shows a fixed refrigeration plant at the Unikai terminal in Hamburg.

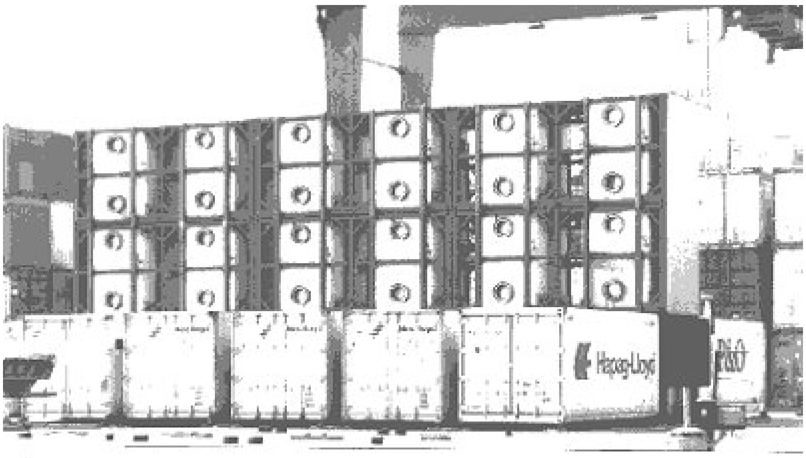


Figure 6: Permanently installed refrigeration system for porthole containers at the HHLA Unikai terminal

Figure 7: Tower units used to supply cold air to porthole containers at the HHLA Burchardkai terminal

7.1.3 Cold air supply on trucks/trains

When transporting goods by rail or by road, clip-ons may be used to supply cold air to porthole containers, in which case a generator is needed to deliver the required 3-phase power.

In Australia and the USA, clip-ons using liquid nitrogen for refrigeration are also occasionally used. The advantage of this is that no external power supply is required to operate such units.

Figure 8: Transport rack for the return transport of clip-on units for porthole containers (without clip-ons)

7.1.4 Shipping line services with porthole containers

Table 3 shows the most important shipping line services and routes for container ships with porthole containers. For various reasons, the partners involved in the individual services, the ports and cargo output are constantly changing. In the year 2000, 90 vessels were still used to provide these services.

No.	Route	Service	No. of ships	TEU	R-TEU
1	Australia - Europe	ANZECS	14 - 16	27,000	15,000
2	Europe - Caribbean	CAROL	5 - 8	9,000	2,500
3	Europe - Caribbean	CGM	4	6,000	3,600
4	Europe - South America	EECSA	15 - 20	25,000	7,000
5	Europe - South America	EUROSAL	5 - 8	12,000	3,000
6	South America - USA	COLUMBUS	2	2,400	1,000
7	Australia - New Zealand - USA	PACE	12 - 16	17,000	8,000
8	Europe - South Africa	SAECS	8 - 10	20,000	6,000

Table 3: The most important shipping lines and routes for container ships with porthole containers

Figure 9 reveals more detail. It shows that there are also a number of minor services, such as Australia/New Zealand - Persian Gulf or Europe (Mediterranean) - Venezuela, which employ a small number of ships and are thus less well-known.
On the other hand, it is clear that a service between Europe and Australia, for instance, travelled around Africa without calling at South Africa. Due to the different heights of the various porthole containers, these services cannot simply be swapped.

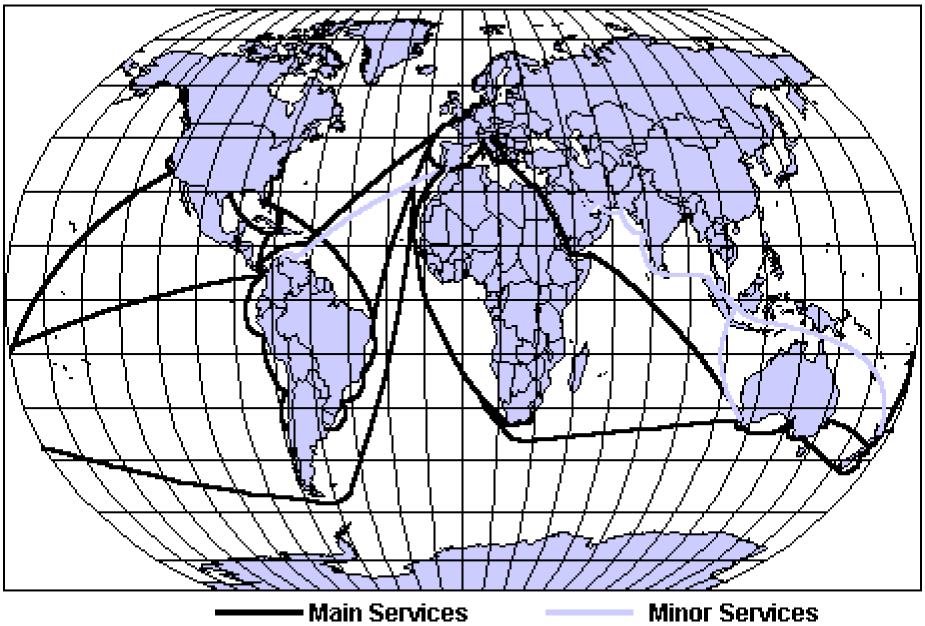


Figure 9: International porthole container services (status 1996 - since then, the service on the Australia-New Zealand-US West Coast route has already switched to integral containers)

The refrigerated cargo on these services is primarily meat, fish and a small quantity of fruit, mainly seasonal fruit, which means that 20' porthole containers were used almost exclusively. The CAROL service (Caribbean Overseas Lines, begun in 1977) was the first to use 40' porthole containers, since fruit is the main refrigerated cargo exported from the Caribbean. Subtropical fruit, such as bananas, pineapples, mangos, melons and avocados are transported all year round with this service. This was followed by the CGM banana service and the EUROSAL service, both of which also use 40' porthole containers since they have a similar refrigerated cargo mix.

In the Australia service, for instance, meat provides a constant volume refrigerated cargo, while seasonal fruit provides additional cargo in the months from December to June and requires clip-on units for porthole containers and increasingly integral containers on deck during peak periods.
7.1.5 Ships and slots

Porthole refrigerated container ships were developed during the pioneering phase of international container ship transport. The new models of this pioneering phase (1969 -1984) were originally the result of the containerization of new North-South trade routes (Table 3) with a medium (20 - 30%) to high (> 50%) proportion of refrigerated cargo.

No.	Route	Service	No. of ships	TEU	R-TEU
1	Australia - Europe	ANZECS	14 - 16	27,000	15,000
2	Europe - Caribbean	CAROL	5 - 8	9,000	2,500
3	Europe - Caribbean	CGM	4	6,000	3,600
4	Europe - South America	EECSA	15 - 20	25,000	7,000
5	Europe - South America	EUROSAL	5 - 8	12,000	3,000
6	South America - USA	COLUMBUS	2	2,400	1,000
7	Australia - New Zealand - USA	PACE	12 - 16	17,000	8,000
8	Europe - South Africa	SAECS	8 - 10	20,000	6,000

Table 3: The most important shipping lines and routes for container ships with porthole containers

The bar chart in Figure 10 clearly shows the various phases. From 1981 onward, only a small number of new vessels were built. As indicated above, the process started with the Australia service to Europe and the USA (1969-1977). This

was followed by the South Africa-Europe service in 1977/78 and then the Caribbean-Europe services in 1977/79 (CAROL, CGM with bananas). The Europe-South America services were containerized between 1981 and 1985 and now serve the East and West Coasts. The new models supplied between 1981 and 1985 were intended for the Europe-South American East Coast service (EESCA) and the West Coast service (Eurosal).

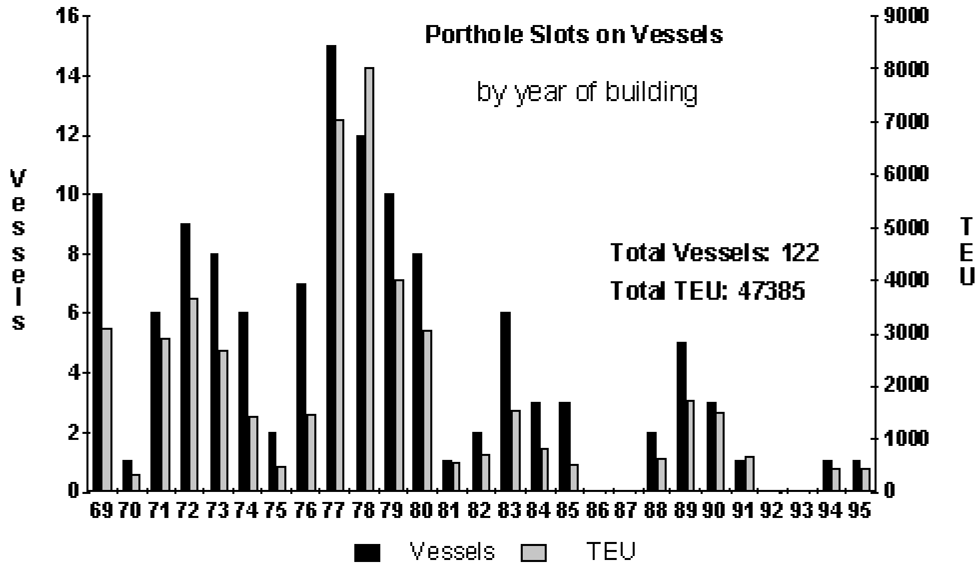


Figure 10: Number of porthole ships built and number of porthole slots

The Eurosal service began in 1984/85 with six ships for 130 x 40' porthole containers (260 PR-TEU) and 100 refrigerated container power outlets on deck for 40' integral refrigerated containers (200 IR-TEU). This signaled the new trend toward transitional ships with porthole containers below deck and integral containers on deck.

The new ships which were brought into service after 1984 were primarily replacements for older or unsuitable ships or additional ships needed to supplement and consolidate individual lines by offering more frequent voyages. This was caused by an increase in the volume of cargo and an improved infrastructure in the relevant countries in terms of road and rail transport of the containers inland. Only then could the benefits of containers in the closed cold chain be exploited in full.

7.1.6 Prospects

Although the discussion regarding the future of the porthole system persisted through to the middle of the 1990s, the decision has since been taken not to build any more ships of this type. The individual services will be completely converted to integral containers by 2006/2008. One of the first services affected by this has been the porthole service from Australia/New Zealand to the US West Coast. The porthole service from Australia/New Zealand to Europe was converted to integral containers at the end of 2002 and the service from the East coast of South America will be converted around mid-2005.

The most decisive factor for this conversion was the enormous growth in integral containers (see Section 7.3 below) and the accompanying pressure from the market. The disadvantages of the integral container (higher energy consumption during transport below deck, higher maintenance costs, increased handling during transport below deck) are regarded as acceptable.

7.2 Integral refrigerated containers

7.2.1 How do integral refrigerated containers work?

In contrast to porthole containers, integral refrigerated containers are equipped with their own refrigeration unit. This normally relies on a three-phase electrical power supply. For information on the electrical data of this container type, see Section 8.1.

Cold air flows through and around the goods in the container. This air is blown in through the gratings in the floor and then drawn off again below the container ceiling. The circulating fans then force the air through the air cooler, which also acts as the evaporator in the cold circuit, and back through the gratings into the cargo (see Figure 11).

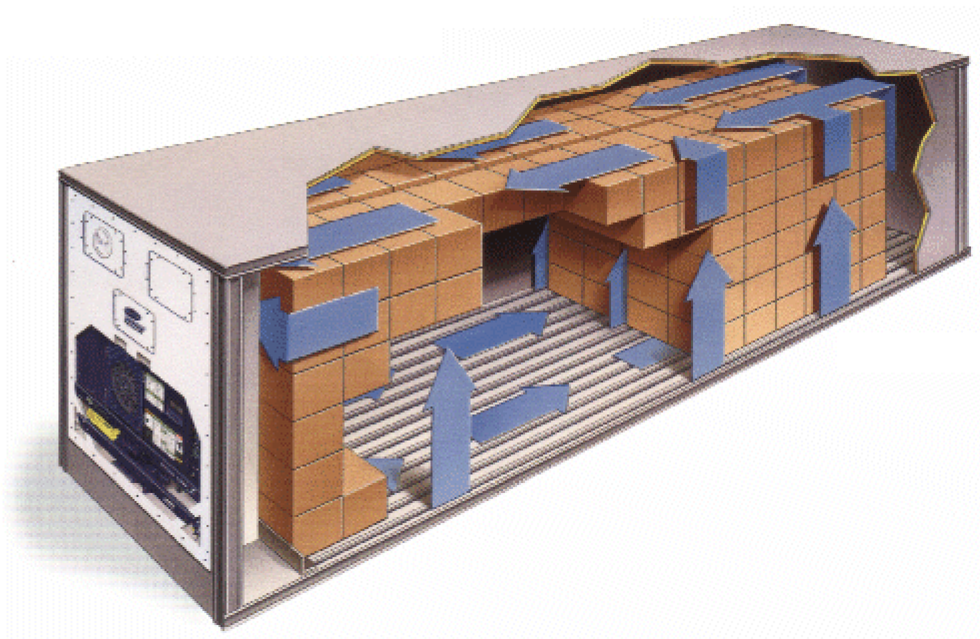


Figure 11: Air flow in an integral refrigerated container

In the case of precooled frozen goods, air only has to flow around the goods, since no heat has to be dissipated from the goods themselves. Only the heat which penetrates the insulation from outside has to be dissipated.

When transporting fruit, however, air flows through the goods, as fruit and vegetables generate respiration heat internally which has to be dissipated.

To ensure that air can flow around frozen goods, without however interrupting the normal flow of circulation while transporting fruit, the inner walls of the container normally feature corrugations. Then, even if the goods are stacked directly up against the wall, air will still flow through these channels and heat penetrating from outside will be dissipated.

Air exchange rates today are approximately 30 - 40 changes/hour when transporting frozen goods and approximately 60 - 80 changes/hour when transporting fruit. The pressure differential at the circulating fan (difference in pressure between the pressure side and the suction side) for normal stowage is approximately 12 - 25 mm H_2O, but other values are possible, depending on the stowage, the power supply frequency and the extent to which the fresh air flaps are opened. Some newer container models have variable speed fans, where the speed is determined by the temperature differential between the supply air and the return air.

The goods must be stowed in the container in such a way that the air flow is not interrupted, for instance by stowing the goods too far above the red load limit line, and to avoid circulation bypasses, for instance as a result of free space in front of the door (where necessary, suitable measures must be taken to cover the grating here).

The container should only be precooled before loading if the container is loaded at an airlock, for instance in a cold store, so that the temperature outside the opened doors is approximately the same as the temperature inside the container. Otherwise, when the doors of a precooled container are opened, water will condense on the walls which may cause subsequent damage to the cargo.

7.2.2 Refrigeration units for integral containers

Refrigeration units for integral containers are available from various manufacturers. The width and height of the units are defined as well as the arrangement of the screws for fastening the unit inside the container. In principle, only the depth of the unit is variable, although all manufacturers are endeavoring to design the devices to be as flat as possible, so as to retain as much usable loading space in the container as possible.

Today, there are two main major manufacturers on the market in addition to a number of smaller companies who often only manufacture small series of special units, for instance for refrigerated tank containers.
7.2.3 Components of an integral refrigerated container

Figure 12 shows the front end of a Carrier Transicold 69NT refrigeration unit. In this instance, all the inspection flaps have been opened. Two circulating fans can clearly be seen towards the top. These force the air through the air cooler below. Single-phase fan motors are mainly used nowadays, to prevent the direction of rotation from changing in the event of the phases in the three-phase power supply being reversed. These motors usually support two rotation speeds, allowing a high speed to be used at high temperatures (above -10°C) and a lower speed for freezing temperatures below -10°C.

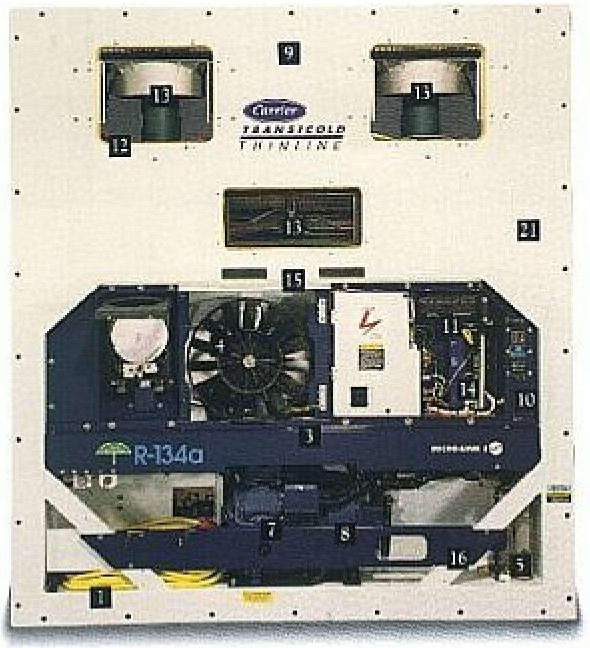


Figure 12: Front end of an integral refrigerated container (Carrier Transicold 69 NT) with components visible

The expansion valve is attached to the air cooler and accessible through the middle inspection flap.

The condenser of the cold circuit is positioned behind the blue cross bar beneath the condenser fan. The condenser fan sucks air over the coolant compressor through the condenser.

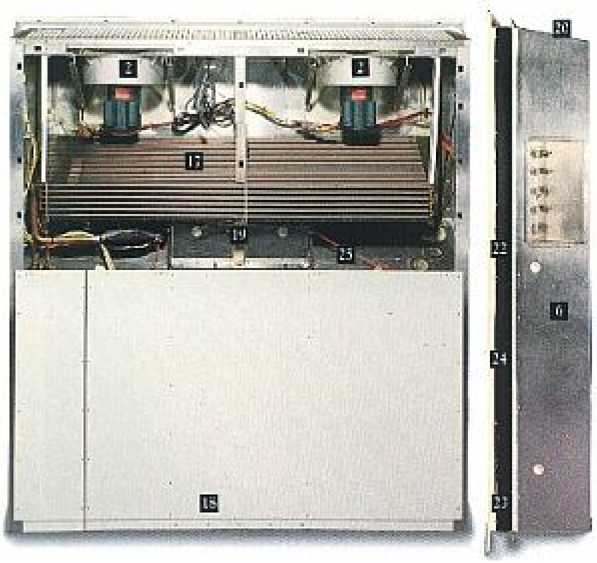


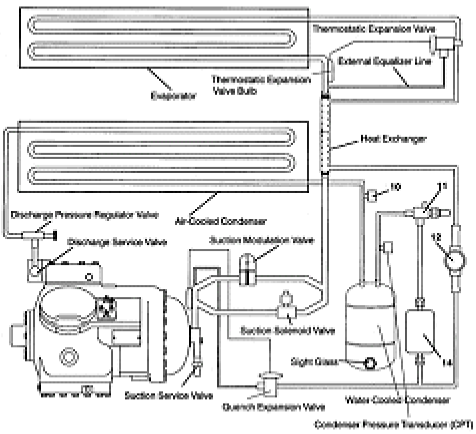
Figure 13: Rear of an integral refrigerated container (Carrier Transicold 69 NT) with visible components and side view

The circulation fans and the air cooler can be seen clearly again in the rear view (Figure 13).

The electric heaters used to heat the container and to defrost the air cooler are also positioned in the air cooler. The drip tray below the air cooler is also electrically heated.

The side view shows the connections for USDA temperature sensors used to measure the temperature of the goods. These temperature sensors are mandatory by the USDA as a proof of insect extermination.

In the event of the container being connected to an on-board water-cooling system, the cooling circuit can be optionally equipped with a water-cooled condenser, as shown in Figure 14.



Click on graphic to enlarge.

Figure 14:
Cooling circuit of an integral refrigerated container (Carrier Transicold 69 NT) with additional water-cooled condenser

First, the coolant flows through the air-cooled condenser, but the condenser fan will not operate if water pressure is detected.

Figure 15 shows the cooling water connections to a water-cooled condenser. These couplings are described in ISO 1496-2, but some banana shipping companies use other couplings.

Figure 15: Cooling water connections to integral refrigerated containers;
return flow - left,
supply flow - right

7.2.4 Fresh air

When transporting fruit and vegetables, i.e. respiring cargo (respiration processes, biotic activity), the carbon dioxide and ethylene produced by the goods must be removed from the container (except of course when using CA). To do this, the containers have fresh air flaps through which fresh air is admitted into the container and air can escape from the container. This exchange of fresh air is caused by the pressure differential between the circulating fans, i.e. fresh air is drawn in on the suction side of the fans and dissipated on the pressure side. The quantity of fresh air supplied is no greater than approximately double the container volume per hour, but depends to a large extent on the pressure differential of the fan and thus on the way the cargo is stowed in the container.

Figure 16 shows the fresh air flap of a container. The discs used to fine control the fresh air supply were specially fitted for the shipping company. The small hose connection at the bottom is the "atmosphere sampling point". This enables the gas composition in the container to be measured even if the fresh air flap is closed.

Figure 16: Fresh air flap on a container. The discs used to fine control the fresh air are special equipment.

7.2.5 Coolant compressors

Presently there is a marked trend among coolant compressors away from piston compressors toward scroll compressors. The benefits of scroll compressors are obvious:

- Fewer moving parts, therefore fewer repairs needed
- Fully air-tight construction, therefore less coolant loss
- Significantly lighter weight and more compact design, making handling easier when exchanging the compressor and increasing the loading capacity of the container
- Develops less noise

7.2.6 Coolants

Originally, all refrigerated containers were operated using the coolants R11 and R12. After the destruction of the ozone layer became an issue and consequently these coolants were banned by the Montreal Protocol, a number of manufacturers switched briefly to R22 as a substitute coolant. However, as this is also being phased out, the two coolants R134a and R404a are now generally used instead.

Currently, however, it is likely that R134a will also be banned, so that the next round of changes in coolants can be expected in around 2010.

7.2.7 Controllers

Refrigeration units are nowadays controlled and regulated by electronic controllers. Depending on the features of the

device, these controllers perform a variety of complex tasks. It must be noted that the controllers themselves are very often a cause of problems. Much refrigeration damage is caused by faulty controllers or the peripherals associated with them (e.g. sensors). The controllers must therefore be designed to be as robust as possible and to be able to withstand the prevalent ambient conditions in terms of heat, cold and moisture (see Section 8.2).

A complete description of all operating modes, alarms and control characteristics would go beyond the scope of this work. Therefore, only the most important operating modes are outlined here.

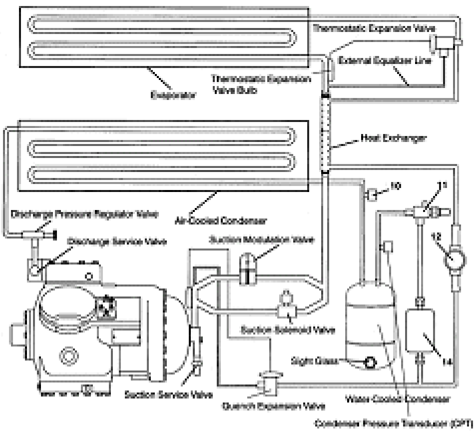
7.2.7.1 Operation for frozen goods

When operating at very low temperatures, below approximately -10°C, small fluctuations in temperature are insignificant. The cooling compressor used to regulate the temperature is therefore switched on and off in this mode, to save energy. The circulating fans are operated at low speed, thereby reducing their power consumption by a factor of 8. The temperature is regulated by means of the return air temperature, i.e. the temperature of the air coming out of the cargo. If this temperature exceeds the nominal value by e.g. 0.2°C, cooling starts (the compressor is switched on), and when the temperature falls e.g. 0.2°C below the nominal value, it is switched off again. To prevent the compressor from constantly switching on and off, a minimum period must have elapsed between two switching operations.

7.2.7.2 Operation for chilled goods

Precise temperature regulation is needed when operating in chilled mode, i.e. above -10°C. This is particularly relevant for the transport of "chilled meat" at -1.4°C and the transport of fruit. The circulating fans operate at high speed in order to improve the temperature distribution in the cargo. In contrast to operation for frozen goods, the supply air temperature is regulated in chilled mode . The cooling compressor runs constantly. Refrigeration performance is controlled by means of butterfly valves in the suction line of the compressor; by means of a hot gas bypass or by other measures on the compressor, such as regular opening of the scroll spiral.

In the Carrier Transicold cooling circuit shown in Figure 14, valves are used to reduce the suction pressure. Both valves remain completely open as long as the supply air temperature is above the nominal value. Once the nominal value has been attained, the suction solenoid valve closes, and the suction modulation valve makes a fine adjustment until refrigeration performance is matched against the heat to be dissipated. If the supply air temperature continues to fall (for instance, because the external temperatures are low), the refrigeration unit switches off completely. If the decrease in temperature still persists, heating is finally switched on.



Click on graphic to enlarge.

Figure 14:
Cooling circuit of an integral refrigerated container (Carrier Transicold 69 NT) with additional water-cooled condenser

7.2.7.3 Defrosting

Below a supply air temperature of approximately +10°C, the air cooler is defrosted at regular intervals, since as of this temperature, the surface temperature on the air cooler can be below 0°C. During defrosting, the circulating fans in the container and the cooling circuit are stopped. The air cooler and the drip tray are electrically heated. Since hot air rises slowly in the refrigeration unit, the return air temperature sensor always shows relatively high temperatures during defrosting.

Defrosting is generally time-controlled, i.e. it occurs e.g. every six, eight or twelve hours. The end of the defrosting process is normally determined when an end temperature is reached at the defrost end sensor above the air cooler. At the same time, however, a maximum defrosting period is also specified. If this is exceeded, defrosting is also terminated.

Some controllers are able to carry out defrosting as and when required. In this case, defrosting is triggered if the supply air temperature is not reached over a specific period or if the temperature differential between the supply air and the return air is too high. Both criteria can indicate an insufficient air flow, which could in turn be caused by ice formation on the air cooler. Other causes are also possible, however, making it difficult to carry out defrosting automatically as required.

7.2.7.4 Special operation modes

A number of special energy saving modes are available to reduce maximum power consumption and/or average

power consumption. For instance, power consumption can be limited by throttling the suction gas. Alternatively, a low fan speed can be used in chilled mode, a method which is advisable for non-respiring goods (e.g. nuts) or in CA mode.

To dehydrate the container, the refrigeration unit can be operated with the heating switched on, so that more water is condensed in the air cooler.

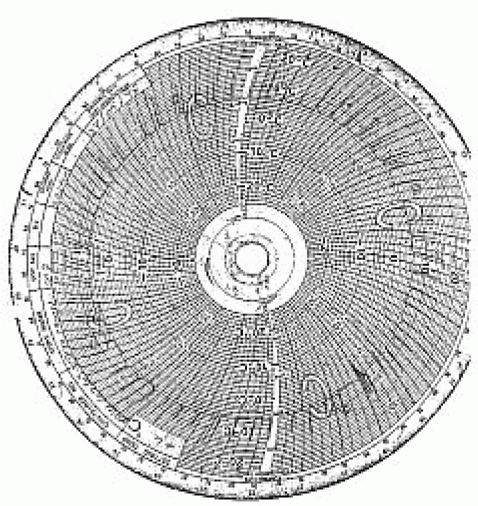
7.2.8 Temperature records

Temperatures generally used to be recorded for use as evidence in the event of a damage claim, mainly with circular temperature charts, which generally cover a period of thirty-one days (see Figure 17). Partlow is one of the main manufacturers of this type of recorder, which is why the charts are also frequently called Partlow charts. The return air temperature is generally recorded on these charts.

Since these circular temperature charts now no longer conform to EU standards, the recorders are rarely installed in new containers, especially as they also represent a significant cost factor.

Due to the progress made in data technology, all new controllers are able to store their measured values on data loggers. The storage period is more than one year. The main benefit of this type of data logger is that it records not only the return air temperature but also the supply air temperature and USDA temperatures. In addition, they can register alarms, on and off times and manual intervention.

One disadvantage of the data loggers is that they only supply discrete values and do not provide the crew with a quick overview of the history of a particular refrigerated cargo transport. In addition, it is often difficult in the event of a damage claim to localize the container and have the contents of the data logger read out.



Click on the graphic to enlarge.

Figure 17:
Example of a
Partlow temperature chart

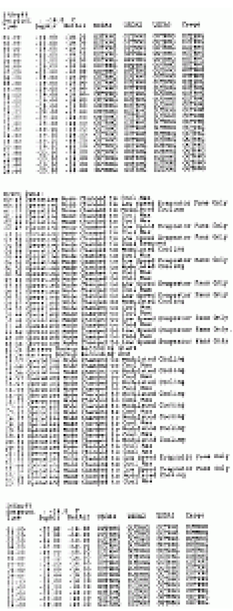


Figure 18:
Example of a
datalogger extract

Click on the graphic to enlarge.

7.2.9 Remote monitoring

7.2.9.1 Systems available

With an increasing number of integral refrigerated containers being used in maritime transport, there is also a greater need for effective ways of monitoring these containers. On ships, many of which can nowadays transport over 1,300 integral refrigerated containers, using a remote monitoring system can cut the costs of inspecting the containers while also enabling the crew to react more rapidly to potential problems in the event of a refrigeration unit failing.

7.2.9.1 Systems available

There are two basic types of monitoring system:

With the four-wire monitoring system, a separate monitoring cable with four wires is used to record the status messages "Compressor running", "Defrost" and "Temperature in Range". Around 50-70% of all refrigerated containers have a socket to connect them to this type of monitoring system.

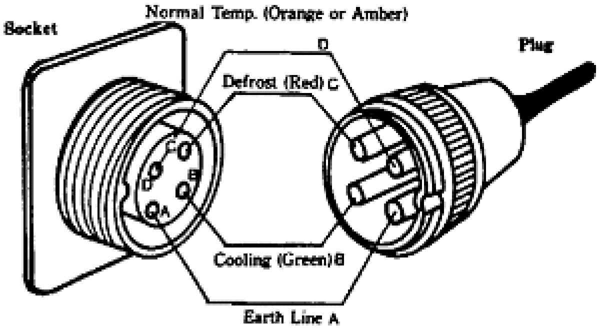


Figure 19: Four-wire socket and plug

With the power cable transmission (PCT) system, however, data is transmitted via the three-phase power cable of the containers. This enables an unlimited amount of data to be transmitted between the container and the receiver on board or on land. The data can be exchanged in both directions, so that it is also possible, for instance, to change the nominal value of the temperature of a container in this way. What is particularly significant in terms of its cost-saving potential is the option of making remote pre-trip inspections (PTI) of the containers on board or in the terminal, as well as to read out data logger information after a journey.

Two different variants of the PCT system are also currently available: Narrowband transmission, which operates at a fixed frequency to modulate data upon the power supply system, and wideband transmission, in which data is transmitted in a frequency spectrum. Unfortunately, the two systems are not compatible with each other, which means that they have to be installed on board depending on the equipment on the containers to be able to communicate with all containers. Out of approximately 360,000 integral refrigerated containers worldwide in 1997, approximately 24,000 (= approximately 6.6%) were equipped with narrowband modems and approximately 19,000 (= approximately 5.3%) with wideband modems. Which of these is used depends very much on the shipping line and the route.

It is expected that it will be possible to transmit data by radio frequency in the future, e.g. using "wireless LAN" technology.

7.2.9.2 Four-wire monitoring

In the four-wire (4-pole) monitoring system, a 4-wire cable is used to transmit three signals as active 24 V signals with a common return wire. The common return wire is generally connected to the chassis of the container. By checking for a connection between this return wire and the ground wire of the container, it is possible to determine whether a container is connected to the four-wire monitoring system.

On a ship or at a terminal, every refrigerated container slot must have the relevant sockets available to connect the signal cable. These sockets are often integrated directly into the refrigerated container power outlets. The signals from the individual containers are transmitted from there either via a field bus system or via the available power networks to the evaluation computer. The signal cables themselves must also be available.

One of the main disadvantages of four-wire technology is its contact problems. Although signal sockets on the containers and on the ships are equipped with protective flaps, the sockets still regularly suffer from corrosion due to the rough environment. The cables are also prone to damage as they are often subjected to rough treatment when twist locks and lashing rods are dropped. Sometimes the cables are also simply torn off, because no-one removed them before unloading the containers.

Since the signals are transmitted as voltage signals with the statuses 0 V and 24 V, it is impossible to determine whether or not there is a reliable electrical connection. It would have been more advisable to use a procedure for monitoring whether a wire is intact (e.g. 4-20 mA signals). However, this was not agreed when this technology was introduced.

The three signals provided by four-wire technology each have a different meaning. The most important signal is undoubtedly "Temperature in Range". If this is not issued, this triggers an alert. Very simple monitoring systems can therefore only evaluate this signal. "Defrost" and "Compressor running", however, are status signals which are required to provide further information. The "Defrost" signal, for instance, can be used to suppress a temperature alarm (during defrosting, it is to be expected that the temperature will deviate from the nominal value). A cooling compressor which is constantly running (Compressor running) in low-temperature mode can indicate a fault in the container.

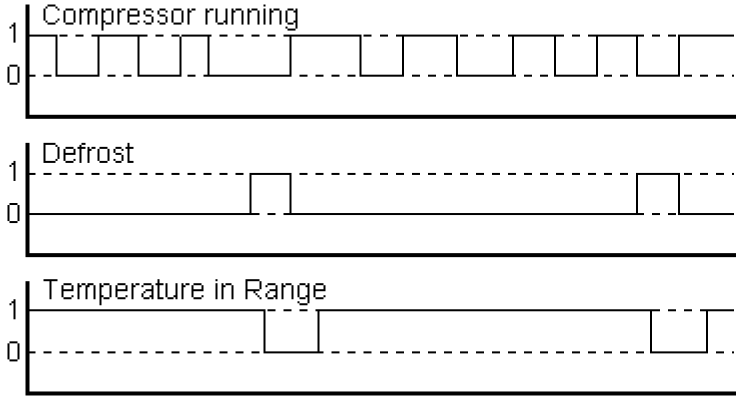


Figure 20: Typical signal behavior of a low-temperature refrigerated container (not to scale)

Figure 20 shows an example of the signal behavior of a correctly functioning low-temperature refrigerated container: During normal cooling operation, the cooling compressor runs in on/off mode. The compressor is switched off during defrosting and must immediately switch on again after defrosting and remain running for longer than usual, so as to dissipate the defrost heat which has accumulated. The "Temperature in Range" signal will not be issued during defrosting, since the air in the cooling unit is being heated, but must be issued again later.

7.2.9.3 Power cable transmission

Power cable transmission naturally eliminates all the problems which arise from using an extra cable in the four-wire monitoring system. It also has a significantly larger range of functions, since any data can be transmitted - it merely (!) depends on the transfer protocol used. The data is modulated onto the three-phase power supply system of the ship or the terminal as a high-frequency signal and received by one or more master modems. It is then transmitted from there via a bus system to the control computer.

To cover longer distances, different types of technology are used by different providers. A system with a capacitive network (Figure 21) only needs one master modem, which is connected to the three-phase power supply system over a kind of signal line and one or more capacitive bridge units (CBUs). To bridge transformers, transformer bypass units (TBUs) are available.

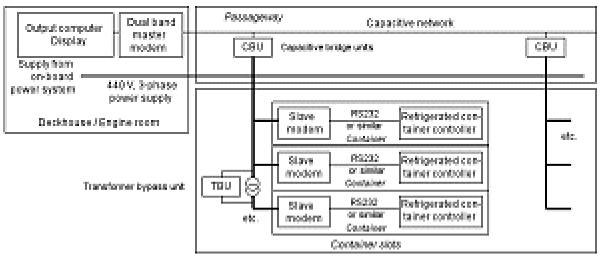


Figure 21: Schematic diagram of the Dual Band Power Line transmission system from RTE/Lyngsø, H.M. Stein Sohn and ASI

(Click on the graphic to enlarge)

The other system uses a number of master modems which are connected to each other via a field bus (Figure 22). The number of master modems required depends on the network configuration and the distances to be covered. The disadvantage of this is that no more than one master modem may be running at a time. This significantly reduces the effective average data transfer rate in the event of several master modems. In addition, it is fairly likely that some

containers are positioned in the catchment area of a number of master modems, meaning that the same data is transferred several times unnecessarily and then needs to be filtered out.

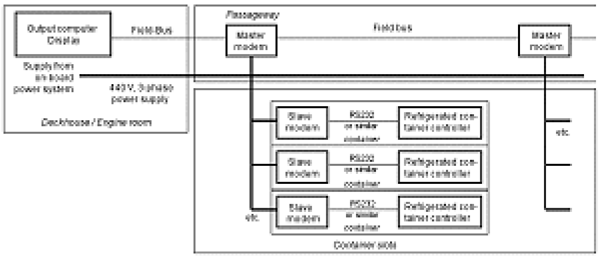


Figure 22: Schematic diagram of the wideband Power Line transfer system

(Click on the graphic to enlarge)

7.2.9.3.1 Narrowband

Data transmission via narrowband is the older of the two methods. Data is modulated onto the power supply network at a fixed carrier frequency of approximately 55 kHz. It is transmitted at a rate of 1,200 baud, which is why this system is often also referred to as a "low data rate system".

Sealand were already carrying out their first trials with PCT at the end of the 1970s. At the beginning of the 1980s, ThermoKing collaborated with Sealand to develop the first marketable system, known under the name of ThermoNet. Sealand and Matson were the first to use this system on a large scale, principally in the relatively closed refrigerated container trade routes in the Pacific.

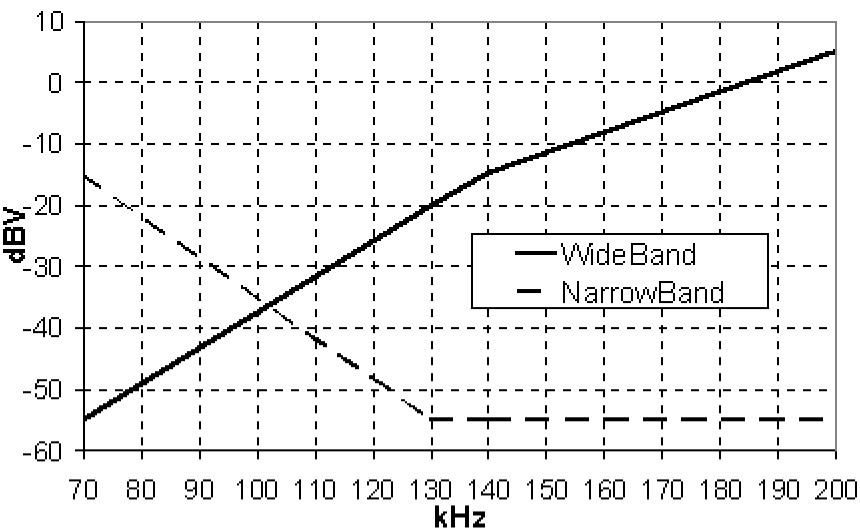


Figure 23: ISO filter specification for wideband and narrowband

7.2.9.3.2 Wideband

In the middle of the 1980s, the wideband system arrived, transmitting data in a frequency spectrum of approximately 140-400 kHz. Transmission over a number of frequencies was intended to ensure reliable transmission even with interference frequencies such as those generated by frequency converters. By distributing the signal over a frequency spectrum, however, the strength of a signal on any frequency is lower than with narrowband, meaning that narrowband manufacturers can lay claim to a greater range.

Since the data transmission rate on wideband systems is theoretically 19,200 baud, it is also known as a "high data rate system". However, reports suggest that in practice this speed benefit is barely discernible.

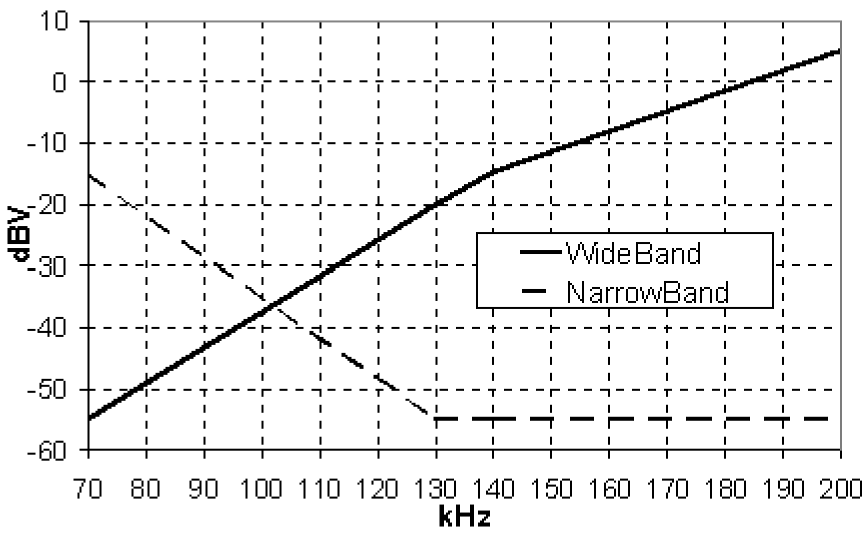


Figure 23: ISO filter specification for wideband and narrowband

7.2.9.3.3 ISO 10368 standard

Experience has proved that it only makes sense to use a monitoring system when there is a standard for data exchange, as genuine saving effects can only be achieved if all refrigerated containers can be monitored by PCT insofar as this is possible. For this reason, an ISO sub-committee was set up between 1987 and 1990 to define a standard. This was finally published as ISO 10368. Since the various companies participating in the committee had different interests, no consensus was reached regarding hardware (i.e. the transmission frequency), and consequently there are still two systems available on the market. Only the frequency ranges for each system were defined, to ensure that they could both be operated simultaneously.

Apart from this, the standard primarily regulates the data transmission protocol (i.e. software) and defines the minimum range of functions for remote communication devices (RCDs).

These functions comprise:

Prescribed queries:

- Identification number of the container or clip-on unit
- Porthole container number (for porthole containers refrigerated with a clip-on unit)
- Date and time of any change to the porthole container number
- Current return air temperature
- Current supply air temperature
- Manufacturer/type

Important optional queries (list not complete):

- Operating mode (Full Cool, Partial or lower capacity cool, Modulated Cool, Fans only, Defrost, Heat)
- Nominal temperature
- Alarms (status query)
- Current alarms (in the order in which they occurred)
- Product temperatures
- Data logger interval
- Power consumption

- Port of destination of the container
- Port of discharge
- Origin
- Results of the self-check (PTI)

Commands for controlling and programming (insofar as the controller of the refrigerated unit supports them):

- Change the nominal temperature
- Start self-check (PTI)
- Change the identification number
- Change the data logger interval
- Set the date and time of the data logger
- Change the operating mode
- Download data logger information
- Change the porthole container number
- Change the destination

Precise data protocols were not defined for all commands and room was left for subsequent extensions in the form of "private sessions", which can be used by individual manufacturers to transmit proprietary data. This extension facility was used excessively by certain manufacturers, to the extent that many functions available today are transmitted within these non-standardized protocol sections. There is disagreement on which of the protocols should put in the public domain and therefore available to the competition for this type of transmission, and under what conditions.

Overall, the ISO Standard has only documented the two existing systems and prescribed some very basic queries. Even if all transmission protocols were put in the public domain, this would mean today that a separate software driver would have to be available for every modem type. Since the controllers of the refrigeration units and the data loggers which are used also have different ranges of functions and data formats, a large number of drivers is needed to support all potential configurations. Consequently, the ISO Standard has been of little help and only resulted in apparent standardization.

Another issue which was not dealt with by ISO is data protection. In accordance with ISO (and also in practice), all data on all containers equipped with modems is available on the power supply network. It is therefore possible theoretically that third parties with access to the power line network via a master modem can read out and even change information on the containers (e.g. the nominal values). This was never a problem while shipping companies were only using PCT on board their own ships and terminals. Once it began to be used on multi user terminals, however, the network operators (terminal operators) have had to ensure that only authorized persons have access to information on containers which pertains to them.

7.2.9.4 Prospects

It can be said that power cable transmission has hitherto been restricted to shipping companies with a high proportion of refrigerated containers. There is no evidence of all refrigerated containers being generally equipped with modems. Two different systems will still be deployed, which means that the evaluation installations used on ships and terminals must be able to cope with both systems for the foreseeable future in order to effectively exploit the savings potential. Even if it may seem that recent investments are generally being made in wideband, there are still too many narrowband containers to expect them all to be converted to wideband. In the long term, however, the modems of the first generation at least must be upgraded, since the impedance values are too low and this interferes with dual band line transmission.

Figure 24: Carrier MicroLink II refrigeration unit with integral RMC wideband slave modem

Until now, a number of major shipping companies have been operating their systems in relative isolation. Increasingly, they are realizing that when cooperating with other shipping companies, which use the other system, provisions need to be made to ensure that both systems can be used on all ships. This development is of course even more noticeable at the terminals.

A similar situation can be observed regarding the use of four-wire monitoring. It is to be expected that this technology will be replaced by power line transmission, but even then there would still be too many containers in circulation without PCT, but using four-wire technology instead, for it to be possible to give up this technology altogether.

It is expected that future technology will base on radio data transmission, as this promises higher transmission rates and lower susceptibility to interference.

Using satellites to monitor refrigerated containers generally fails, because when the containers are stacked they cover the antennas of the containers below them, thus making data transmission impossible. The same applies when containers are stowed below deck. In future, however, it will definitely be possible to send data transmitted by PCT via satellite from the ship to receiving stations on land, to enable the refrigerated containers to be accessed online.

When transmitting CA data (oxygen content, carbon dioxide content, humidity) by power line transmission, it will be necessary for the controller of the refrigeration unit to forward this data to the slave modem and for the evaluation software to be able to process this data accordingly.

Figure 25: ThermoKing refrigeration unit with integral RTE wideband slave modem

7.2.10 Boxes

The refrigerated containers themselves, i.e. the boxes, are mainly manufactured in Asia today (see Section 7.5). In Europe, only one major supplier and a few smaller suppliers remained in 2002.

Today, container walls comprise CFC-free polyurethane foam with a plastic or aluminum coating on the outside and stainless steel or aluminum on the inner side. The walls are introduced into the container frame and subsequently filled with foam which helps to mechanically strengthen the container. It is extremely important when introducing the foam that no areas with coarse pore foam or even cavities build up, as they would act as thermal bridges and - in connection with CA - would be potential sources of leakage.

ISO 1496-2 also stipulates the requirements of the container with regard to its mechanical loading capacity, quality of insulation and leakproofness. The mechanical tests will not be discussed here.

The heat transition coefficient of the insulation, according to ISO, must be no more than 0.4 W/m²°C.

Leakproofness is tested by checking that the airflow required to maintain a pressure of 250 Pa above atmospheric in the container does not exceed 10 m³/h. This test applies to the container structure and the door gaskets so that all other openings, such as the air cooler drainage, the water drainage apertures in the floor and the fresh air flaps, are closed.

Figure 26: Refrigerated containers with and without integral refrigeration unit

7.2.11 Future trends

Currently, there are four main trends in the development of refrigeration units which are all aimed at reducing energy consumption. This is necessary on the one hand because of the international agreements on CO_2 emissions, on the other hand because increasing oil prices make it economically attractive again.

1. Scroll compressors will replace piston compressors. In addition, scroll compressors are being developed which can be adjusted mechanically so that refrigeration performance is no longer adjusted by throttling the suction line or by means of a hot gas bypass. This will also considerably reduce energy consumption.

2. The circulating fans in the container will in future be variable speed and will be regulated by the temperature differential between the supply air and the return air. Since fans are responsible for a significant amount of a refrigerated container's energy consumption (approximately 2 kW at high speed), and heat produced by the fans also has to be extracted from the container, the highest saving potential is to be expected here.

3. The fresh air flaps will be automatically regulated in accordance with the specified CO_2 content. Reducing the quantity of fresh air can also significantly reduce the refrigeration level required when transporting fruit. An automatic fresh air flap also makes certain CA functions possible (see the chapter on "Controlled atmosphere").

4. Research is still being carried out on new coolants, with a trend toward "natural" coolants, such as butane/propane, CO_2 or water. It will of course be a long time before any of these coolants can be introduced into the refrigerated container sector.

7.3 Comparison between integral and porthole containers

Table 4 and Figure 27 show the trends in the total figures for containers in TEU. It can clearly be seen what a dominant role integral containers have come to play over porthole containers. The annual rate of growth of integral containers is on average approximately 13%, while porthole containers show a marked decline.

Year	**Insulated TEU**	**Integral TEU**	**Total TEU**	**Source**	**Increase in integrals per year**
1978	53,260	52,291	105,551	Containerisation International World Container Census 1999	
1982	72,184	110,710	182,894	Containerisation International World Container Census 1999	20.6%
1986	77,065	157,039	234,104	Containerisation International World Container Census 1999	9.1%
1990	71,505	282,265	353,770	Containerisation International World Container Census 1999	15.8%
1992	73,491	333,461	406,952	Cargoware International Dec. 1992	8.7%
1994	70,973	449,726	520,699	Containerisation International World Container Census 1999	16.1%
1995	71,888	519,684	591,572	Containerisation International Jan. 1996	15.6%
1996	64,187	566,657	630,844	Containerisation International World Container Census 1999	9.0%
1997	60,962	623,822	684,784	Containerisation International World Container Census 1999	10.1%
1998	57,477	696,419	753,896	Containerisation International World Container Census 1999	11.6%
2002	*37,000*	*1,050,000*	*1,087,000*	*Containerisation International World Container Census 1999*	*10.8% forecast*

Table 4:
Overall trends in refrigerated container quantities from 1986 through 1998

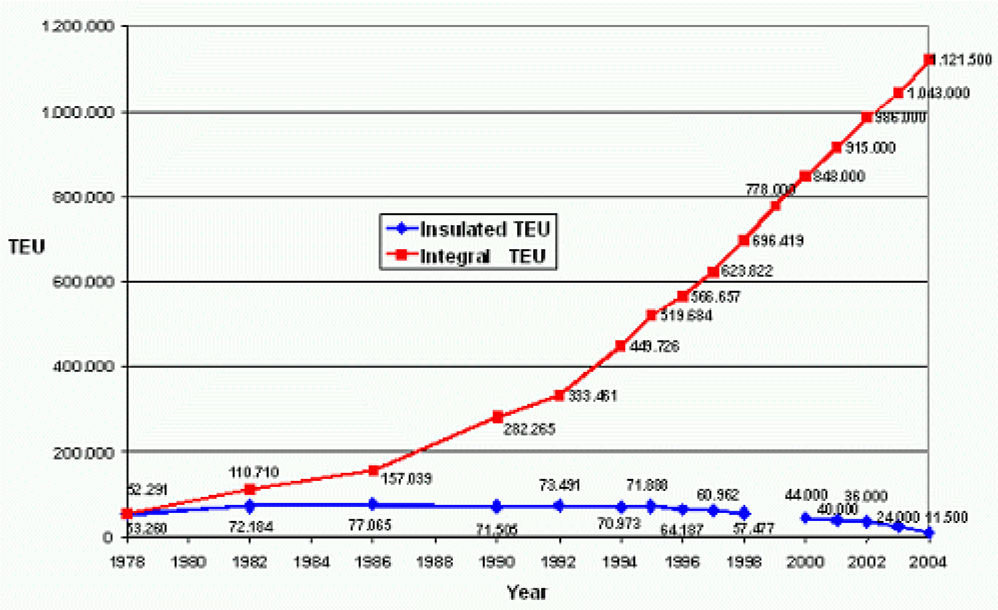


Figure 27:
Overall trends in refrigerated container quantities from 1978 through 2004

7.4 Trends in the size of integral containers

Table 5 shows the relative quantities of all containers with regard to their various dimensions. The largest growth today can be observed in the 40' high cube containers (9' 6" high). In future, they will replace the normal 8' 6" high 40' containers. 20' containers, however, are still needed to transport heavy cargo such as meat and fish, since a 40' container fully loaded with these goods would exceed the 30t weight limit.

	TEU					
	1992	**1994**	**1995**	**1996**	**1997**	**1998**
Integral 20' (8')	997	1,183	1,182	822	661	656
Integral 20' (8' 6")	79,508	100,775	115,106	119,368	118,246	119,811
Integral 20' (9' 6")					370	665
Integral 40' (8')	40	1,356	1,376	40		
Integral 40' (8' 6")	167,680	203,860	205,482	189,846	179,004	176,836
Integral 40' (9' 6")	70,648	131,076	179,570	241,440	314,382	387,464
Integral other	14,588	16,587	16,968	18,636	11,159	10,987
Total integral TEU	333,461	454,837	519,684	570,152	623,822	696,419
Total integral containers	*206,983*	*278,398*	*317,986*	*345,171*	*371,180*	*408,111*
Insulated 20' (8')	46,260	42,600	36,666	38,308	32,021	30,565
Insulated 20' (8' 6")	15,771	17,500	16,167	15,268	19,705	17,524
Insulated 40' (8')	18	18	18	18		
Insulated 40' (8' 6")	8,636	7,502	7,712	7,728	6,886	6,930
Insulated 40' (9' 6")	608	800	1,072	1,290	1,000	1,018
Insulated other	2,198	11,700	10,253	11,024	1,350	1,440
Total insulated TEU	73,491	80,120	71,888	73,636	60,962	57,477
Total insulated containers	*67,761*	*70,110*	*62,361*	*63,606*	*56,344*	*52,783*

Total TEU	**406,952**	**534,957**	**591,572**	**643,788**	**684,784**	**753,896**
Total Containers	***274,744***	***348,508***	***380,347***	***408,777***	***427,524***	***460,894***

Converting TEU to a number of containers where 40' container = 2 TEU
Integral other includes 43' containers from Chiquita, for instance
Source: World Container Censuses

Table 5: Trends in the proportion of different refrigerated container sizes from 1992 to 1998

It is also interesting to look at the actual number of containers, which amounted to 408,777 in 1996. According to table 2, 47.41 million tons of refrigerated cargo were transported by sea in the same year. If it is assumed that approximately 50% of these goods were transported in containers, and that the average weight of a container cargo is 20 t, this means there are a total of 1.185 million transport operations per year. This means an average of 2.9 transport operations per year per container. There are of course large variations depending on the owner and the trade route. Banana companies, who mainly transport their bananas to North America in refrigerated containers, make approximately twelve to fifteen trips per year. The annual frequency with which the major container shipping companies use "normal" refrigerated containers must be reduced accordingly, meaning that an average of around two trips per year can be expected.

7.5 Container production

It is even clearer from the data on annual container production (see Table 6) how dominant high-cube 40' containers are. In 2004, they made up 82% of the global production of TEUs.

Year	20' Integral	40' Integral	40' HighCube Integral	Porthole (Conair / insulated)	Total
1990	11,500	17,000	14,500	4,000	47,000
1991	5,000	8,500	16,000	4,000	33,500
1992	10,000	17,500	24,000	10,500	62,000
1993	12,000	13,000	28,500	4,500	58,000
1994	10,500	13,000	40,000	2,500	66,000
1995	12,500	17,000	50,500	1,000	81,000
1996	11,000	6,500	61,000	500	79,000
1997	11,000	6,500	73,000	500	91,000
1998	10,000	7,000	76,500	500	94,000
1999	11,000	4,500	74,000	500	90,000
2000	9,500	2,500	88,000	1,000	101,000
2001	9,500	500	86,000	1,000	101,000
2002	16,000	300	97,500	1,200	115,000
2003	11,000	200	122,500	1,300	135,000
2004	10,500	200	132,000	2,300	145,000

All figures in TEU

Source: World Cargo News June 2004

Table 6:
Annual production of refrigerated containers from 1990-2004 by size and type

Year	Annual production	Added to fleet	Replaced in fleet	Fleet size at the end of the year
1990	43,000	35,000	8,000	294,000
1991	29,500	23,000	6,500	317,000
1992	51,500	46,000	5,500	363,000
1993	53,500	48,000	5,500	411,000
1994	63,500	55,000	8,500	466,000
1995	80,000	60,000	20,000	526,000

1996	78,500	52,000	26,500	578,000
1997	90,500	68,000	22,500	646,000
1998	93,500	67,000	26,500	713,000
1999	89,500	65,000	24,500	778,000
2000	100,000	70,000	30,500	848,000
2001	96,000	67,000	29,000	915,000
2002	113,800	71,000	42,800	986,000
2003	133,700	57,000	76,700	1,043.000
2004	142,700	78,500	64,200	1,121.500

All figures in TEU

Source: World Cargo News June 2004

Table 7:
Production, increase in stock and replacement of integral refrigerated containers from 1990-2004

The figures on the requirements for replacing container stock (Table 7) are also of interest. They show a very substantial requirement to replace stock has developed since 1994. This reflects the fact that containers built at the beginning of the 1980s have come to the end of their 12 to 15 year working life. It can therefore be assumed that the requirements for replacing stock will increase even further in the future.

Table 8 shows container production and present production capacity by region. The excess capacity in China is particularly noticeable. This excess capacity has led to a dramatic drop in the price of refrigerated containers and a decline in production capacity in other regions. Refrigerated containers are as a result no longer manufactured in the USA, Japan and even South Korea.

Region	Production in 1995	Production in 1996	Production in 1997	Production in 1998	Production in 1999	Production in 2000
South Korea	46,450	38,000	34,200	34,500	35,800	27,500
China	400	4,900	20,500	24,500	31,100	52,000
Japan	11,350	7,400	6,500	3,700	-	-
Taiwan	10,500	5,000	4,500	-	-	-
Mexico	2,500	10,500	6,300	6,000	6,200	-
USA	3,000	3,500	6,500	6,200	1,600	-
Europe	5,500	8,800	12,000	17,000	14,400	21,000
Other	300	400	-	2,100	900	500
Total	80,000	78,500	90,500	94,000	90,000	101,000

Region	Production in 2001	Production in 2002	Production in 2003	Production in 2004	Current production capacity (2004)*
South Korea	2,700	-	-	-	-
China	72,700	94,400	115,000	127,500	165,000
Japan	-	-	-	-	-
Taiwan	-	-	-	-	-
Mexico	-	-	-	-	-
USA	-	-	-	-	-
Europe	21,000	20,000	19,500	17,000	20,000
Other	600	600	500	500	2,000
Total	97,000	115,000	135,000	145,000	187,000

All figures in TEU

*Based on multiple-shift operation
Source: World Cargo News June 2004

Table 8: Production of refrigerated containers by region 1995-2004

7.6 Trends in the container ship fleet

Table 9 shows the overall trends in refrigerated container slots on ships. These also include slots for porthole containers, although they have tended to be on the decrease since the last porthole ships were built in 1995. Since generally one slot is provided for a 40' container on ships other than porthole ships, the actual number of slots is approximately half that shown (1 FEU = 2 TEUs).

Year	Reefer slots TEU	Annual growth rate
1996	267,000	-
1997	305,000	14.2%
1998	358,100	17.4%
1999	403,600	12.7%
2000	418,800	3.8%
2001	457,100	9.1%
2002	531,600	16.3%
2003	592,300	11.4%
2004	746,600	26.1%

Table 9:
Overall trends in refrigerated container slots on ships from 1996 to 1997

All figures in TEU
Source: : Clarkson Container Intelligence Monthly

The number of refrigerated container slots on ships (see Table 9) is gowing at approximately 14% per year, around the same rate at which the number of containers is increasing.

Table 10 shows the development in the size and age of the container ship fleet including the refrigerated container capacity at the end of 1997. A total of some 2,200 were available for transporting refrigerated containers. The large ships with a high refrigerated container capacity which were over five years old in 1997, were ships used to transport porthole containers. Recently built ships are exclusively ships used to transport integral containers. The ships of the "Regina Maersk" group, for instance, have 700 refrigerated container slots, which is equivalent to 1,400 TEUs. The largest refrigerated container ship in the world in 2004, the "Monte Cervantes", owned by Hamburg-Süd, has more than 1,365 slots for 2,450 TEU refrigerated containers. This gives refrigerated containers a share of almost 50% of the overall capacity of the ship of 5,100 TEU.

Age of ships / Refrigerated container capacity TEU	0 - 4 years		5 - 9 years		10 - 14 years		15 - 19 years		20 - 24 years		> 25 years		Total	
	No. of ships	No. of reefer TEU	No. of ships	No. of reefer TEU	No. of ships	No. of reefer TEU	No. of ships	No. of reefer TEU	No. of ships	No. of reefer TEU	No. of ships	No. of reefer TEU	No. of ships	No. of reefer TEU
<100	117	7,688	118	7,527	212	13,520	247	15,533	84	5,475	51	3,219	829	52,962
100-199	246	33,958	130	17,355	147	19,554	135	16,791	59	7,848	47	6,276	764	101,382
200-299	113	24,916	60	13,228	43	9,771	46	10,367	25	5,752	14	3,173	301	67,207
300-399	61	16,783	25	8,108	32	11,042	11	3,630	9	3,074	7	2,556	135	45,193
400-499	24	10,540	15	6,530	4	1,782	5	2,118	4	1,732	3	1,358	55	24,060
500-599	17	8,826	16	8,072	7	3,730	5	2,754	1	593	1	562	47	24,537
600-699			2	1,276	3	1,841	5	3,148	1	622	7	4,673	18	11,558
700-799			7	5,140			1	721			1	758	9	6,619
800-899	4	3,200	7	5,972			7	6,240	1	892			19	16,304
900-999							3	2,815	1	981			4	3,796
>1000	11	14,224					2	2,546	4	4,542			17	21,312
Total	583	119,735	380	73,208	448	61,240	467	66,061	189	31,511	131	22,575	2,198	374,930

Click the graphic to enlarge.

Table 10:
Trends in the size and age of ships with refrigerated container capacity

Figure 28: The "Dole Colombia" refrigerated container ship built by HDW in 1999 with 990 FEU (= 1980 TEU) water-cooled refrigerated containers

8 Technical aspects during transportation

8.1 Power supply

8.1.1 Electrical data in accordance with ISO 1496-2

The key electrical data for integral refrigerated containers are defined in ISO 1496-2. As a fundamental principle, all integral refrigerated containers are operated using a 3-phase a.c. power supply with different frequencies and voltages. It should be emphasized that unlike 3-phase a.c. power supply networks on land, there is no neutral line. Accordingly, the connection cables are only 4-wire (three phases + ground line).

The containers are classified according to two types of network voltage, with a further division made according to the network frequency.

It must be possible to operate type 1 containers on the following power networks:

a)	50 Hz +/- 2.5%:	180 V min.	230 V max.
b)	60 Hz +/- 2.5%:	200 V min.	250 V max.

It must be possible to operate type 2 containers on the following power networks:

a)	50 Hz +/- 2.5%:	360 V min.	460 V max.
b)	60 Hz +/- 2.5%:	400 V min.	500 V max.

There are also containers fitted with dual-voltage systems which allow them to be operated in both voltage ranges. These containers have an additional transformer that is used to convert the network voltage to the relevant operating voltage. A dual-voltage system such as this is optional. The weight of the refrigeration unit increases as a result of the transformer and the second connection cable. As an alternative, mobile transformers are occasionally used at terminals (see Fig. 29).

A general rule is that the maximum power consumption is not permitted to exceed 15 kW or 18.75 kVA. The make current is not permitted to exceed 300 A for type 1 containers and 150 A for type 2 containers. The make current can be reduced by starting the motors sequentially. The make current must fall to to 125% of the rated current within one second.

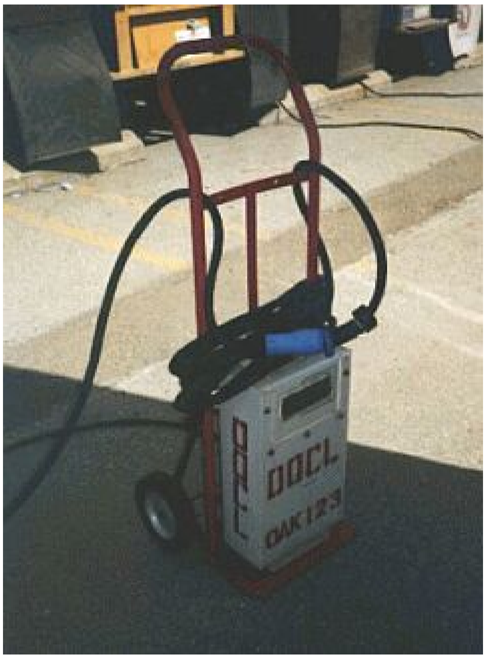


Figure 29:
Mobile transformer used to provide refrigerated containers with 240 V 3-phase power

The insulation resistance to ground must be at least 1 MΩ. The protection class is IP56.

At the moment the responsible ISO committee is working on specifying a maximum leakage current for refrigerated containers. The limit should be around 20 mA. This value appears to be problematic insofar as the defrosting heaters in the evaporator are unable to meet these values after a long standstill, but dry out once they have started operating, thus increasing the insulation resistance.

8.1.2 Actual power consumption

The actual power consumption of an integral refrigerated container will depend on its operating status. Here, a particularly important role is played by the internal temperature of the container which determines the required evaporation temperature of the refrigerant. Generally the higher the internal temperature, the higher the electrical power consumption and the higher the refrigeration capacity that is available. Table 11 shows the refrigeration capacities and power consumption for some of the ThermoKing refrigeration units.

REFRIGERATION CAPACITY
Zer-O™ system net cooling capacities at 37.8°C (100°C) ambient and 60 Hz electric power:

Scroll w/R404A:					Reciprocating w/R134a:				
Container Temperature	Cooling Capacity			Power Consp.	Container Temperature	Cooling Capacity			Power Consp.
	Watts	KCal/hr	Btu/hr	KW		Watts	KCal/hr	Btu/hr	KW
21°C (70°F)	13,771	11,844	47,000	10.7	21°C (70°F)	13,507	11,617	46,100	12.0
2°C (35°F)	9,962	8,568	34,000	9.1	2°C (35°F)	11,456	9,853	39,100	10.5
-18°C (0°F)	5,860	5,040	20,000	6.1	-18°C (0°F)	5,604	4,820	19,127	6.0
-29°C (-20°F)	3,809	3,275	13,000	5.3	-29°C (-20°F)	3,023	2,600	10,317	4.5

Click on the table to enlarge.

Table 11: Manufacturer specifications regarding the refrigeration capacity and the power consumption of a Thermo King Smart Reefer with different compressor types and refrigerants.

All values given in table 11 are maximum values for full refrigeration capacity and an external temperature of 37.8°C. This occurs, for example, when cooling the cargo. One should also bear in mind the fact that the permitted ambient temperature for a refrigerated container is usually 50°C which may result in increased power consumption.

Usually, once the cargo has been cooled, the average power consumption falls. In low-temperature mode (below -10°C) the refrigeration unit is run in on/off mode, whereas in chilled mode (above -10°C) the output of the refrigeration circuit is regulated constantly (e.g. using the suction modulation valve as shown in figure 14). With a 40' container and an ambient temperature of 45°C, average power consumption values of approximately 4.2 kW can be expected for low-temperature operation (-21°C) and 7 - 8 kW for transporting bananas (+16°C).

For a very broad average value for all container types, ambient conditions and cargo types, the value 3.6 kW/TEU can be used. A 20' container tends to be closer to 4 kW and a 40' container tends towards 7 kW. As a result of new developments and the associated improvements in the efficiency of the containers, this value is dropping.

8.1.3 On board

The power supply on board is provided by the electric power generation system of the ship. The generators are either powered by auxiliary diesel motors with capacities of up 4 MW and/or using a shaft generator driven by the main engine. Since the main engine runs at different speeds depending on the current speed of the ship, it will be necessary to use a frequency converter when using a shaft generator in order to ensure that the power supply frequency remains constant. This may lead to high-frequency harmonics in the power supply frequency which may in turn lead to problems with electronic components. In particular, operating a power line monitoring system (see below) is often made more difficult as a result.

On ships with a relatively small number of slots for refrigerated containers, the generators usually run at the on-board voltage/frequency of 460 V / 60 Hz, although other voltage/frequency combinations are also found. On the other hand, if there are large numbers of refrigerated container slots, a medium voltage busbar is used (2 to 4 kV) because otherwise the current levels are too high. In order to supply the refrigerated containers with power, this voltage must be transformed down to the operating voltage used by the container.

Some ships do not have sufficient generator capacity to power the refrigerated containers, and thus, during peak times, mobile diesel generators housed in 20' containers are made available on deck. These can either supply the refrigerated containers directly or the power they generate flows into the onboard.

The onboard power supply network is usually rather erratic and is subject to frequent fluctuations in frequency. Since these networks are always small isolated networks, any special considerations need to be taken into account.

8.1.4 On land

Providing a power supply on land is usually not a problem, the containers can be connected to a main power supply network. The only thing to bear in mind is the fact that there is no neutral line. A frequency of 50 Hz, which is usually the found in Europe, means that the speed of the motors is reduced and thus their capacity.

8.1.5 Transport by rail/road

When transporting containers by road or by rail, a so-called gen-set (generator set) is used for longer transport times. These generators are either attached to the end of the container (see Fig. 30) or under a trailer (Fig. 31).

The capacity of these gen-sets is again governed by ISO 1496-2, which means that they are designed to provide 15 kW of power at the most.

Figure 30: Generators (gen-sets) for supplying power for integral containers can be mounted on the front of the container

Figure 31: Generators (gen-sets) for supplying power to integral containers can also be mounted under the trailer

8.2 Ambient conditions

ISO 1496-2 does not specify the maximum ambient temperature at which a refrigerated container must operate correctly. The only specification is that for the purposes of testing, the cooling capacity must be 125% of the heat load that passes through the walls at an ambient temperature of 38°C and a temperature inside the container of -18°C. With the types of insulation in common use today this lies between 3 and 3.5 kW. These values are far exceeded by the refrigeration units that are available today, as can be seen from table 11. Here, the cooling capacity at -18°C is approximately 5.7 kW.

However, for practical reasons, the following applies:

- The mechanical protection mechanisms of the refrigerated circuit should not trigger when the refrigeration unit is at a standstill or as a result of sunlight. So, for example, with ambient temperatures of between 70 - 80°C it should not be possible for a pressure valve to open and release refrigerant. The Carrier Transicold 69NT40 refrigeration unit has, for example, a protection pane with a bursting pressure of 35 bar. According to the vapor pressure curve for the refrigerant R134a, this corresponds to a temperature of approximately 94°C.

- Obviously, other components of the container also should not suffer damage at a temperature of 70 - 80°C, when the refrigeration unit is at a standstill or as a result of sunlight.

- The electronics of the device should not fail when subjected to sunlight. Here also, temperatures of -80°C - 80°C may be considered realistic.

- It must be possible to operate the refrigeration unit under the ambient temperatures that occur in practice. The highest temperatures that can be expected occur when transporting refrigerated containers below deck or when operating on an asphalt surface exposed to the sun. A maximum value of 50°C is generally assumed but this is not specified in any standard.

- Values of -30°C to -40°C are considered realistic values for the lower limits for the ambient temperature. At these temperatures also, no damage should occur.

- All system components must be sufficiently protected to ensure they will operate in the rain or when exposed to salt water when stowed on deck.

Conditions of this nature are usually listed in the specifications issued by shipping companies.

8.3 Heat dissipation

8.3.1 Heat to be dissipated per container

The amount of heat that is to be dissipated per container will depend on a number of influences, for example, the operating status, the internal temperature, the external temperature, the cargo that is currently loaded, etc. The maximum amount of heat that is dissipated by a container can usually be derived from the manufacturer's specifications. These maximum heat values usually only occur in cooling operation if the goods do not have their nominal temperature. They are made up of the heat that is drawn from the cargo as a result of cooling it, plus the heat generated by the electrical processes used to drive the compressor and fans.

The Smart Reefer from ThermoKing (the manufacturer specifications can be seen in table 11) has a maximum heat dissipation of between 24.5 and 25.5 kW at 21°C (cooling bananas), 20.5 through 22.0 kW at 2°C, 11.6 through 12.0 kW at -18°C and 7.5 through 9.1 kW at -29°C.

REFRIGERATION CAPACITY
Zer-O™ system net cooling capacities at 37.8°C (100°C) ambient and 60 Hz electric power:

Scroll w/R404A: Container Temperature	Cooling Capacity Watts	KCal/hr	Btu/hr	Power Consp. KW	Reciprocating w/R134a: Container Temperature	Cooling Capacity Watts	KCal/hr	Btu/hr	Power Consp. KW
21°C (70°F)	13,771	11,844	47,000	10.7	21°C (70°F)	13,507	11,617	46,100	12.0
2°C (35°F)	9,962	8,568	34,000	9.1	2°C (35°F)	11,456	9,853	39,100	10.5
-18°C (0°F)	5,860	5,040	20,000	6.1	-18°C (0°F)	5,604	4,820	19,127	6.0
-29°C (-20°F)	3,809	3,275	13,000	5.3	-29°C (-20°F)	3,023	2,600	10,317	4.5

To enlarge the table click

Table 11: Manufacturer specifications regarding the refrigeration capacity and the power consumption of a Thermo King Smart Reefer with different compressor types and refrigerants.

These specifications by and large match those of Carrier Transicold. Here the author measured heat dissipation of 26 kW during the cooling of bananas.

Since refrigerated containers usually arrive on board in a pre-cooled state, this maximum heat dissipation is not the average heat dissipation. In low-temperature operation, the containers reduce the refrigeration capacity by switching the refrigeration unit on and off, whereas when running in chilled mode above approximately -10°C the refrigeration capacity is reduced by throttling the suction line. In reality, the heat dissipation of a cooled banana container at an ambient temperature of +45°C is approximately
12 - 13 kW, or for low-temperature operation approximately 124 - 5 kW.

The actual average heat dissipation depends very much on the type of cargo, and hence on the route and the season. In order to obtain a rough estimation of the average energy consumption and thus the average heat dissipation, the consumption figures for approximately 2,600 TEUs were recorded on a P&O vessel traveling the route from Europe to East Asia. The results are shown in Fig. 32.

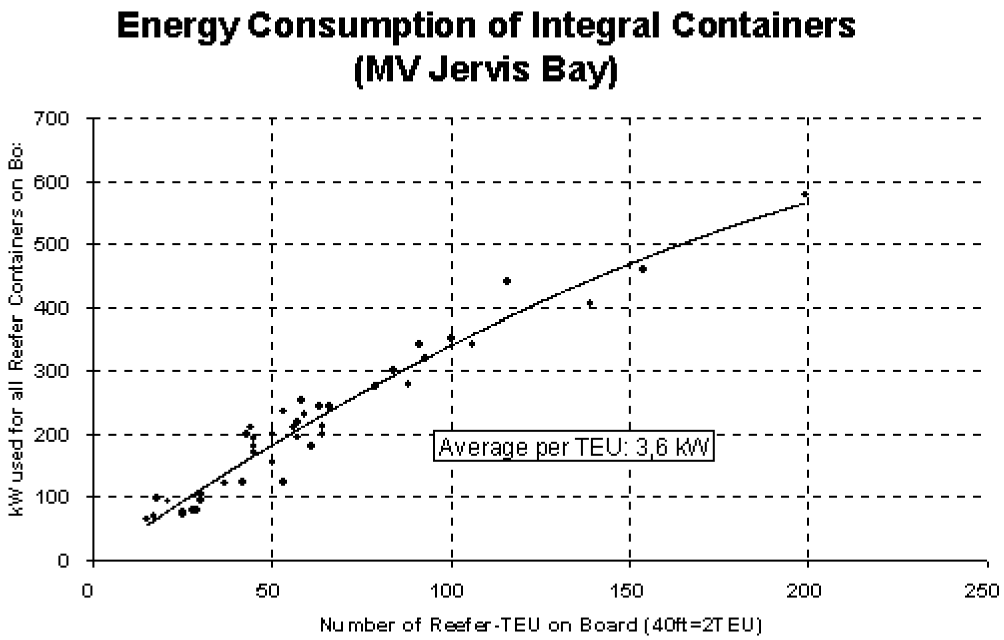


Figure 32: Average electrical power consumption of refrigerated containers on the Europe-East Asia route on a P&O vessel

The average value per TEU is approximately 3.6 kW, although the average for 20' containers is closer to 4 kW per container and 7 kW per 40' container because of the better surface/volume ratio.

8.3.2 Heat dissipation when transporting refrigerated containers below deck

When transporting refrigerated containers on deck, heat dissipation rarely causes problems. However, if refrigerated containers are transported below deck, which is increasingly the case, the heat produced by the containers must be removed from the hold. Depending on the length of the journey, the types of containers used and the predominating cargo, it may be necessary to dissipate between 7 kW and 15 kW of heat per 40' container. At the moment three methods are used:

8.3.2.1 Heat dissipation processes

1. Cooling with fresh air only: With this method, the ambient air on deck is drawn in and passed to each refrigeration unit with an air distribution system. If the vessel has a closed hold, it may also be necessary to install appropriate air extraction fans. A system of this type is shown in Fig. 33. The power requirements for a cooling system of this type, will depend on the design and the vessel type, and vary between 1.5 kW and 5 kW for each 40' container.

2. Fresh air cooling with return cooling by sea water: With this method, air cooled by the sea water air cooler is circulated through the hold. This process is usually only used where it is not possible to achieve the necessary airflow cross-sections in the deck structure. The energy expenditure of this system is no more efficient than that of a cooling system using only fresh air.

3. Sea water cooling of the containers: This method requires the use of specially designed containers which have a water-cooled condenser in addition to the usual air cooled condenser (see above). Water for cooling is then piped to the containers by the ship. However, some of the electrical power consumed must be dissipated with air from the hold since the hot parts of the refrigeration unit also give off heat to the air in the hold. A particular disadvantage of this method is that it is not suitable for use with all types of refrigerated container

and thus results in very serious logistical limitations.

The general conclusion is that the removal of heat generated by refrigerated containers stored below deck requires a considerable amount of energy. Since the refrigeration units of the refrigeration containers usually have a maximum permitted ambient temperature of +45°C, this is also the maximum permitted air temperature when designing systems.

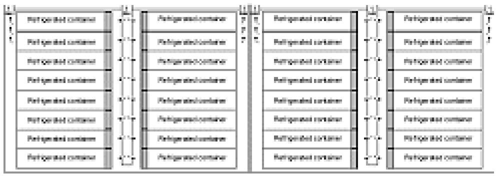


Figure 33:
Ventilating a hold with refrigerated containers

Click the graphic to enlarge.

8.3.2.2 Heat dissipation using fresh air

Table 12 provides an example of the design calculation for a fresh air cooling system with an external air temperature of 35°C and a relative humidity of 70%. Since the heat generated by the air supply fan also needs to be taken into account, the total amount of heat that must be dissipated is increased by this value.

This results in a required fresh air volume of approximately 60 m³/min for each 40' container. Some shipping companies, for example, P&O Nedlloyd, specify values of 100 m³/min in their construction regulations, since the maximum incoming air temperature in regions such as the Suez canal can be greater than 35°C. Germanischer Lloyd recommends 75 m³/min in their latest set of ventilation regulations and thus also assumes external temperatures above 35°C.

Design of an air cooling system for refrigerated containers with mechanical air supply

Sources of heat			
Number of refrigerated containers	100		
Quantity of heat per container:	10 kW		
Container heat to be dissipated:	1,000.0 kW		
Fresh air flow per container	60.0 m³/min		
Air flow:	360,000.00 m³/h		
Approx supply air fan capacity (same for return air):	163.64 kW	2,200 (m³/h)/kW	
Total quantity of heat to be dissipated:	**1163.64 kW**		
Heat dissipation			
Incoming air temperature:	35 °C	P_{Ds}	5,621.6 Pa
Moisture content	80.0 %	P_D	4,497.3 Pa
Enthalpy on entry	110.27 kJ/(1+x)kg	x	0.029287621 kg/kg
Specific heat (per kg of air):	10.30 kJ/kg		
Exit temperature:	**44.73 °C**		
Exit moisture:	47.6 %	P_{Ds}	9,448.4 Pa
Exit enthalpy:	120.56 kJ/(1+x)kg	P_D	4,497.3 Pa
Exit dew point:	31.0 °C		
Air density:	1.13 kg/m³		
Quantity of dissipated heat:	**1,163.64 kW**		
Overall energy requirements			
For powering the fans:	163.6 kW		
Total	**163.6 kW**		

Table 12: Energy equation for cooling with air

8.3.2.3 Heat dissipation using return air cooling processes

On the vessels of the APL China class, HDW used a system which circulates air in the hold and cools it using sea-water cooled return air coolers.

This system requires similar quantities of air as when using fresh air cooling only, since with a sea water temperature of 32°C it is barely possible to achieve a supply air temperature lower than 35°C. The only real advantage of a system of this nature is that it is possible to avoid the large openings in the deck that would otherwise be required to allow the passage of air to and from the hold.

8.3.2.4 Heat dissipation using water for cooling

Heat dissipation using water for cooling is only possible with specially designed containers and, today, is only really used by shipping companies that do not have partnership agreements with other shipping companies.

The water supply to the container usually uses fresh water which is cooled by sea water. The intended incoming temperature is thus approximately 35°C. The water-cooled condensers of the container are resistant to sea water which would theoretically allow operation with sea water, but this method is usually avoided due to the risk of corrosion.

The maximum cooling water flow is approximately 30 l/min at a pressure loss of around 1.2 bar. The maximum return air temperature when cooling bananas is then approximately 45°C with a heat yield of approximately 24 kW.
8.3.2.5 Heat dissipation using evaporative cooling processes

When using evaporative cooling methods, the evaporation heat of the water can be used to cool the air. This is done by spraying a fine aerosol of water into the air where it completely vaporizes if possible. This is often achieved with a fan where the water is sprayed into the air flow produced by the fan, or compressed air is used to create the aerosol. Today, typical applications include: greenhouse and shopping mall cooling systems (e. g. in the USA).

This method of heat dissipation can, in principle, also be applied to refrigerated containers. There are a number of particular benefits:

- Refrigerated containers are designed to be operated under damp conditions anyway (rain/sea spray).
- Condensation is to be expected in the hold of a ship carrying refrigerated containers, which means that paintwork etc. must be waterproof anyway. Holds are always designed with bilge sumps to pump off any water.
- As a result of the space limitations with regard to installing ventilation ducts, this procedure is the only way of dissipating more heat in conjunction with the existing ventilation system. It is thus particularly suitable when upgrading a vessel.

The water sprayed into the air for evaporation must be obtained on board using a suitable treatment method to produce fresh water. It would be tempting to use sea water, but this would lead to serious problems in terms of erosion of the spray nozzles and salt deposits in the hold.

Obviously, evaporative cooling systems must be accompanied by ventilation of the hold using fresh air, but this can be at a lower level than when using air cooling systems alone. When using a combined system like this, the quantity of fresh air can be reduced from 60 m^3/h to 30 m^3/h compared with cooling systems using fresh air only. Despite evaporation, the relative humidity drops (!) from 70% at the air inlet to 52.1% at the air outlet.

The quantity of water necessary for evaporation will only be required during normal operation for a few hours a day because the ambient temperature drops at night. Since water is easy to store, the system can be run with a buffer.

This method is particularly interesting if an existing ventilation system is required to extract more heat than is possible with a fresh air cooling system alone.

8.4 Temperature records in refrigerated containers

8.4.1 Introduction

8.4.2 How do refrigerated containers work?

8.4.2.1 Air flow and regulation

8.4.1 Introduction

When transporting refrigerated containers, maintaining the cold chain often causes problems. For this reason it is necessary to maintain temperature records in order to provide evidence of the temperatures during transport. Since a refrigerated container is a complex system, a variety of different temperatures in a number of operating modes can be measured and recorded. The interpretation of temperature records of this type is a constant source of disagreement.

The following sections will show what options are available for recording temperatures, as well as the various possible meanings of the recorded temperatures and how these can be assessed.

8.4.2 How do refrigerated containers work?

8.4.2.1 Air flow and regulation

A refrigerated container is always cooled by blowing cold (supply) air into the grating located under the cargo, this then passes through the container floor and flows through and around the cargo and finally at the top of the container it is extracted to the refrigeration unit (return air). The "warmed" return air is then cooled in the air cooler of the refrigeration unit and blown back into the container as described.

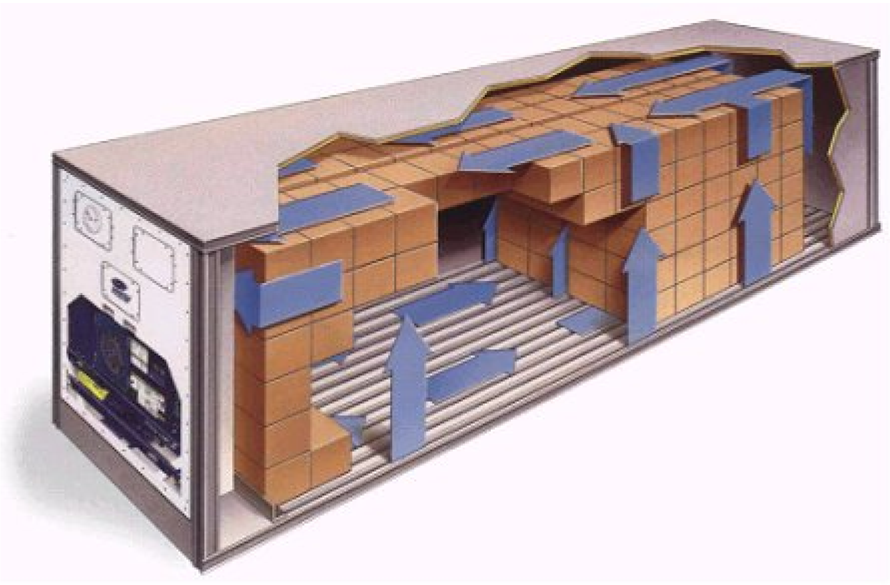


Figure 34: Air flow in a refrigerated container

The supply and return air temperatures are measured and recorded in the refrigeration unit. Under normal operating conditions the return air temperature is between 0.5°C and 3°C higher than the supply temperature because the return air is carrying the heat from the container itself. This heat is made up of the heat that comes from the ambient environment outside the container through the container insulation, any heat caused by cooling the load, and when transporting fruit the respiration heat of the load itself.

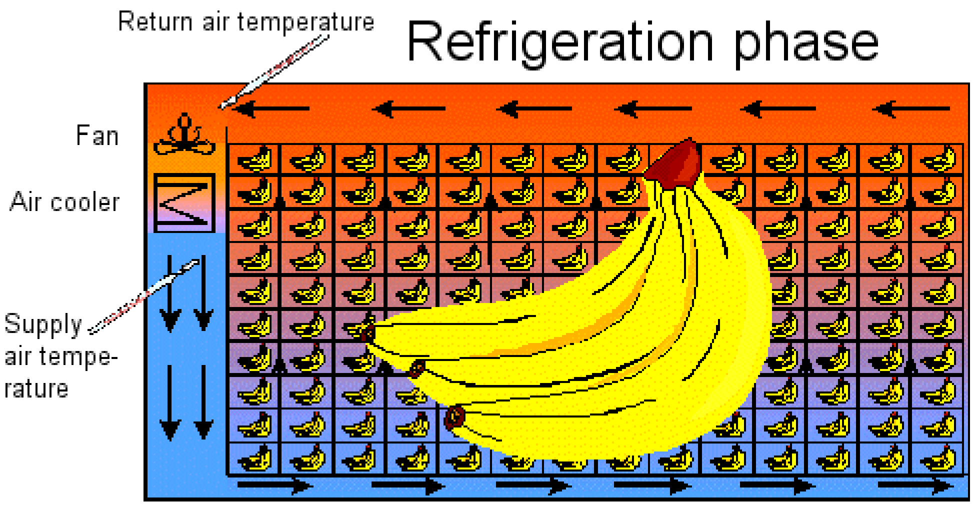


Figure 35:
Air flow and temperature distribution in a refrigerated container during refrigerated operation

In low-temperature mode, most common refrigeration units control the return temperature using a two-point switching method: As long as the return air temperature is above the nominal value, the refrigeration unit cools at full power. Once the nominal temperature has been reached, the refrigeration unit switches itself off leaving only the fans responsible for circulating the air in the container running. When the return air temperature rises to approximately 0.5°C above the nominal value, the refrigeration unit starts up again and the process is repeated. The supply air temperature must obviously be lower than the nominal temperature.

The circulating fans are operated at low speeds in low-temperature operation to ensure that the air is exchanged at a rate of 30 - 40 times the empty container volume per hour.

From time to time the air cooler must be defrosted in order to prevent it from becoming iced up and thus reducing the flow of air and the transfer of heat. During this process the cooling unit is switched off and the circulating fans are stopped to ensure that no warm air is able to enter the container. The frequency of defrosting can be specified manually. However some refrigeration units are able to determine automatically when defrosting is necessary. In addition, manual defrosting can be triggered at any time using the switch on the refrigeration unit.

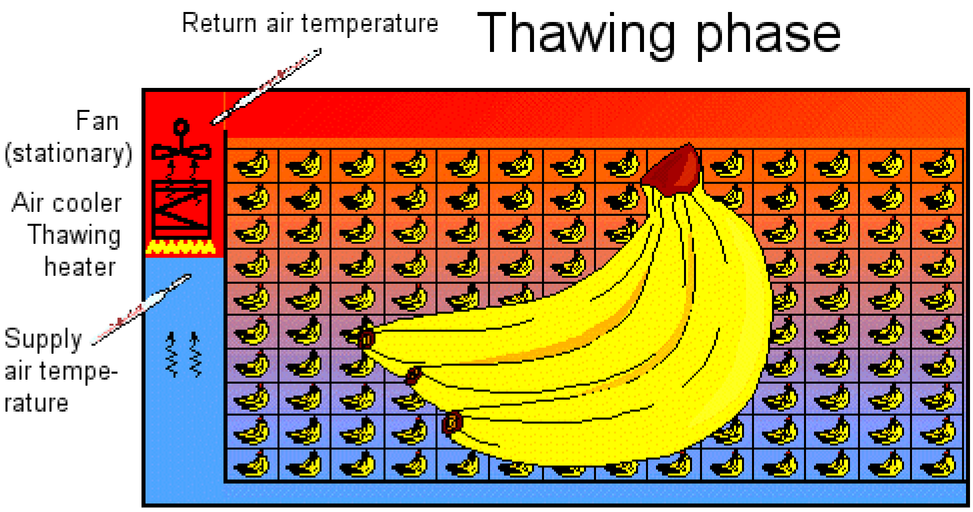


Figure 36: Defrosting a refrigeration unit

Unlike low-temperature operation, in chilled operation with nominal temperatures above -10°C, the supply air temperature is regulated constantly. The refrigeration unit is running constantly, except when it is defrosting, and the supply air temperature is regulated with the regulating valves in the refrigeration circuit of the refrigeration unit. In addition, in chilled operation the circulating fans run at full power providing an air exchange rate within the container of between 60 - 80 circulations/hour.

8.4.2.2 Temperature records

As already described, the supply and return air temperatures are measured in the refrigeration unit since the regulation mechanism reacts to one of these two temperatures depending on the operational status of the unit. In addition, refrigerated containers are equipped with a number of different types of temperature recording devices.

8.4.2.2.1 Circular temperature charts

The circular chart recorder is still the most widespread method of temperature recording. This is often referred to as a Partlow chart because Partlow is one of the major manufacturers of recorders of this type. The recorders usually have their own temperature sensor. This is filled with a fluid that expands and contracts as the temperature changes and transfers the temperature data to the pointer mechanically. These recorders are thus independent of the regulation circuit of the refrigeration unit. However, there are also models of container where the recorder is controlled electronically by the refrigeration unit controller.

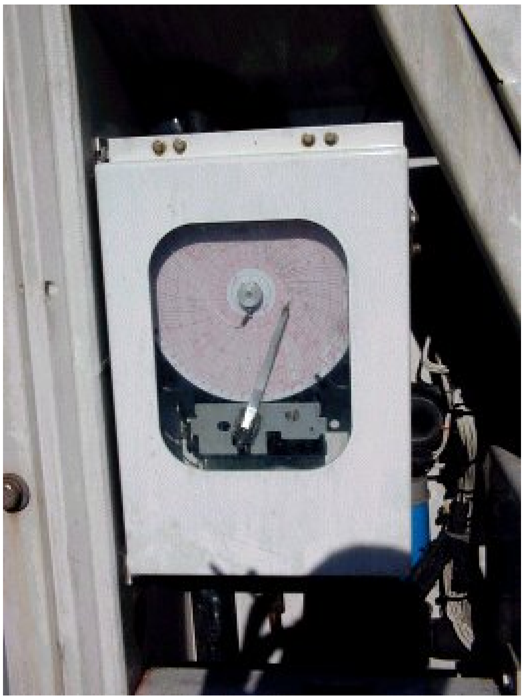


Figure 37: Circular temperature chart recorder

Generally the return air temperatures are recorded since these can be used to draw conclusions about the temperature of the cargo. However, there are some exceptions. Some refrigeration unit models record the supply air temperature and some record the maximum value of the supply air and the return air. Recorders that record both the supply and the return air temperatures are rare. With recorders of this type it must be remembered that there is a time lag between the two recorded temperatures which generally makes it difficult to pinpoint times accurately.

The recorders are either fitted with a spring wound mechanism that must be wound when the chart is put into place, or they are electrically-driven. During times when the container is without a power supply, the recorder is powered by a battery.

The recording is made on pressure-sensitive circular charts similar to carbonless paper. The stylus of the recorder puts pressure on the chart and thus draws a line. These charts should never be used as a support when writing, since this pressure would also leave a mark. Its is also recommended that charts should be protected by card when they are sent by post to avoid accidental pressure being applied.

These charts usually record 31 days of data (a single revolution), but there are recorders and charts designed to record a week's worth of data.

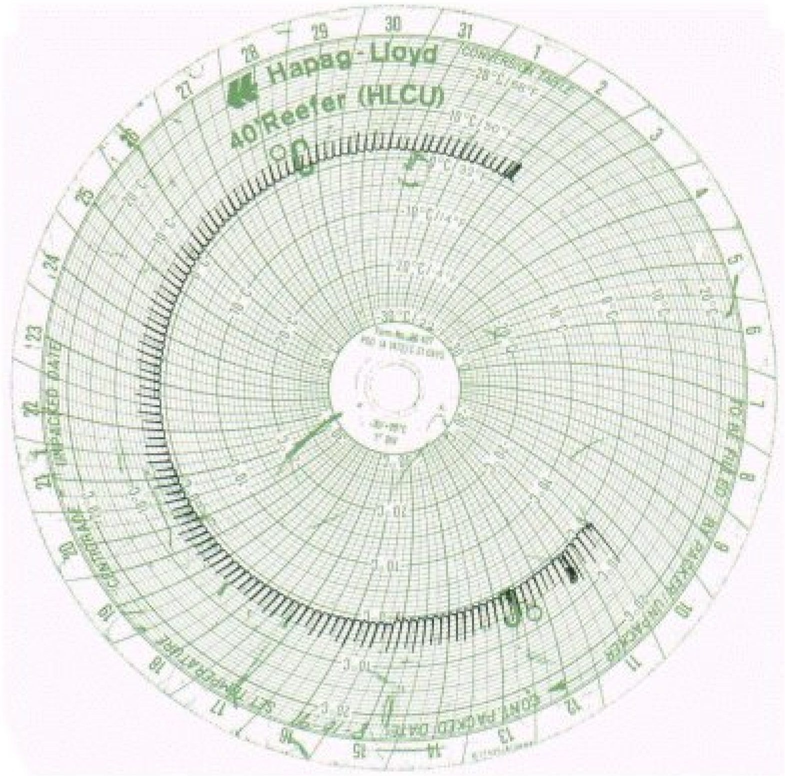


Figure 38: A circular temperature chart from a refrigerated container

Figure 38 shows a typical temperature record on a chart of this type. The regular temperature peaks show the defrosting operations which, in this case, took place every four hours. These defrosting peaks can be very different in character and are influenced by the stowage method in the container, the length of the defrosting period, the nominal temperature as well as the position of the sensor. They are caused by the fact that during defrosting, warmed air rises from the air cooler and comes into contact with the return air temperature sensor.

8.4.2.2.2 Data loggers

Today, increasing numbers of data loggers are being used. These record both the supply and return air temperatures and also return information about alarms, ambient temperatures, pre-trip inspections, USDA temperature sensors and other information. A considerable proportion of refrigerated containers are only equipped with data loggers of this type and no longer with the traditional recorders. The trend today is away from recorders and toward data loggers.

Unlike the circular temperature charts, the data loggers record the temperatures digitally which provides only a discrete number of measured values. The normal recording interval is one hour. However special events such as alarms, defrosting process etc. are all saved explicitly. Depending on the type of logger and the way it is programmed, the recorded temperature data may be snapshot values or may be average values over a defined period of time.

```
22Nov99
Setpoint  : 1.0  C
Time      SupAir  RetAir  USDA1   USDA2   USDA3   Cargo

01:00      0.95    1.70   OUTRNG  OUTRNG  OUTRNG  OUTRNG
02:00      0.95    1.60   OUTRNG  OUTRNG  OUTRNG  OUTRNG
03:00      1.10    1.65   OUTRNG  OUTRNG  OUTRNG  OUTRNG
04:00      2.20    4.50   OUTRNG  OUTRNG  OUTRNG  OUTRNG
05:00      0.95    1.65   OUTRNG  OUTRNG  OUTRNG  OUTRNG
06:00      0.95    1.55   OUTRNG  OUTRNG  OUTRNG  OUTRNG
07:00      0.95    1.55   OUTRNG  OUTRNG  OUTRNG  OUTRNG
08:00      0.95    1.50   OUTRNG  OUTRNG  OUTRNG  OUTRNG
09:00      0.95    1.40   OUTRNG  OUTRNG  OUTRNG  OUTRNG
10:00      2.20    4.00   OUTRNG  OUTRNG  OUTRNG  OUTRNG
11:00      0.95    1.70   OUTRNG  OUTRNG  OUTRNG  OUTRNG
12:00      0.95    1.50   OUTRNG  OUTRNG  OUTRNG  OUTRNG
13:00      0.95    1.50   OUTRNG  OUTRNG  OUTRNG  OUTRNG
14:00      0.95    1.50   OUTRNG  OUTRNG  OUTRNG  OUTRNG
15:00      0.95    1.40   OUTRNG  OUTRNG  OUTRNG  OUTRNG
16:00      0.95    1.30   OUTRNG  OUTRNG  OUTRNG  OUTRNG
17:00      2.20    5.50   OUTRNG  OUTRNG  OUTRNG  OUTRNG
18:00      0.45    1.60   OUTRNG  OUTRNG  OUTRNG  OUTRNG
19:00      0.55    1.25   OUTRNG  OUTRNG  OUTRNG  OUTRNG
20:00      0.55    1.20   OUTRNG  OUTRNG  OUTRNG  OUTRNG
21:00      0.55    1.20   OUTRNG  OUTRNG  OUTRNG  OUTRNG
22:00      0.55    1.15   OUTRNG  OUTRNG  OUTRNG  OUTRNG
23:00      0.55    1.15   OUTRNG  OUTRNG  OUTRNG  OUTRNG
24:00      1.10    4.25   OUTRNG  OUTRNG  OUTRNG  OUTRNG

Event Data:
02:43 Defrost Start due to timer
02:43 Operating Mode Changed to Defrost
03:11 Defrost End due to Normal operation
03:19 Operating Mode Changed to Cool Reduced
03:19 Operating Mode Changed to Modulated Cooling
09:19 Defrost Start due to timer
09:46 Defrost End due to Normal operation
09:54 Operating Mode Changed to Cool Reduced
09:54 Operating Mode Changed to Modulated Cooling
15:54 Defrost Start due to timer
15:54 Operating Mode Changed to Defrost
16:01 Battery Backup Recording Start
17:28 Battery Backup Recording End
17:28 Setpoint Change with keypad 0.60 C
17:32 Operating Mode Changed to High Speed Evaporator Fans Only
17:33 Operating Mode Changed to Modulated Cooling
23:30 Defrost Start due to timer
23:30 Operating Mode Changed to Defrost
23:58 Defrost End due to Normal operation
```

Figure 39: Extract from a data logger file of a Carrier Transicold Container

8.4.2.2.3 Temperature recorders in the load

Nowadays, several data loggers are often also placed within the load when transporting refrigerated goods. These are used to monitor the temperatures inside the container during transport and allow this data to be made available to the recipient of the goods. These loggers can provide evidence of periods of insufficient refrigeration leading to damage. For certain highly sensitive products (for example, blood plasma) the use of such loggers is required as proof that the cold chain has not been broken at any time.

Figure 40:
Mechanical and electronic
Ryan recorders for recording temperatures in the load

The devices currently available on the market are supplied by a number of manufacturers and range from clockwork-driven analog recorders that write data to a strip of paper right down to digital data loggers that use infra-red interfaces to transfer the data. Depending on the features,prices start at around $ 50 (valid 2000). The accuracy of the analog devices is approximately +/-1°C, and the digital devices are accurate to +/-0.1°C. Taking into account the value of the cargo and the potential costs of compensation for damaged goods, the cost of using a recorder is negligible and their use is to be recommended for all consignors. The recorded data is not only useful in providing the consignor with data as evidence against the transporter, but is also useful in providing evidence for mistakes made by third parties, for example, the terminals.

When choosing where to place these loggers, care should be taken to ensure that they are placed in temperature-critical locations in the container so that they measure the actual cargo temperature. It thus makes sense for them to be located in a box on the top layer close to the door.

Placing recorders of this type on top of the cargo is, however, not to be recommended as this measures the temperature of the air rather than the temperature of the cargo. This may give rise to far-reaching discussions about whether the cold chain has been maintained. Figure 41 shows an example of a record of this type. The clearly visible temperature peak in the middle of the printout shows an increase in temperature of approximately 10°C within the space of thirty minutes, but can only reflect a change in air temperature since it would not have been physically possible for the cargo temperature to have increased this much during this period of time because of its mass and the heat capacity of the cargo (see Section 8.4.3.1 for more information). A sharp increase in air temperature, as shown here, is perfectly possible in the event that the refrigeration system fails, since the air in the container very quickly starts to form layers where the warmest air is located just below the container roof.

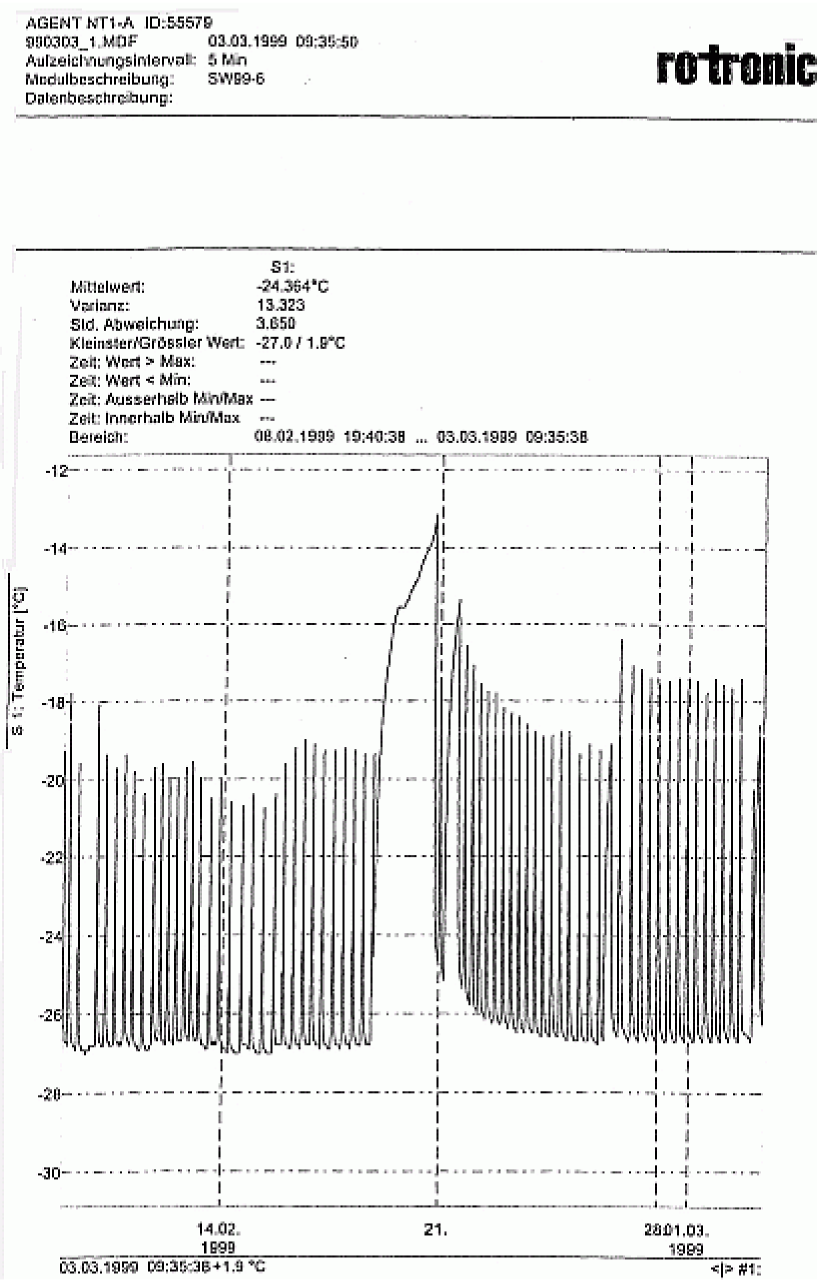
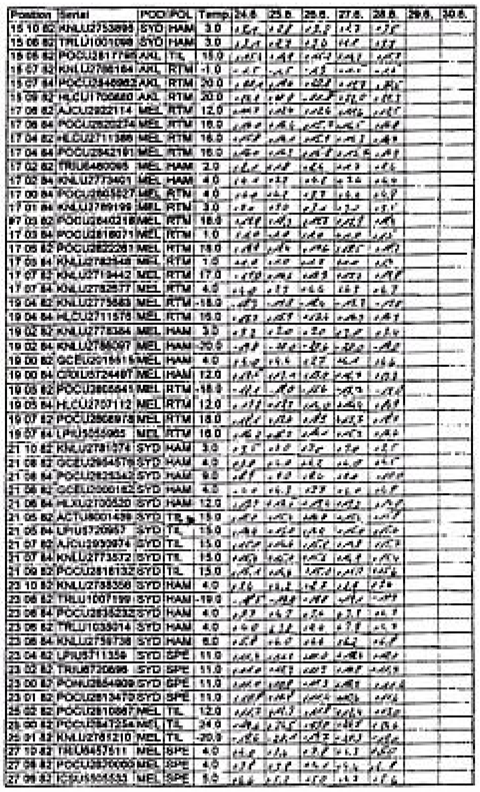


Figure 41: Printout from an electronic data logger from Rotronic placed in the cargo

8.4.2.2.4 Manual temperature records

On board ship - and as long as the weather conditions permit this - the refrigerated containers are inspected at least once a day and the current temperatures are recorded manually. These records are used, in the first instance, to prove that the crew of the vessel have done their duty with regard to the care of the containers. The daily rounds are required in order to locate defective containers and to carry out appropriate repairs.

Generally the recorded temperature is the one shown as the current value by the container controller. This is usually the temperature that is to be regulated, thus in low-temperature operation it is the return air temperature and in chilled operation it is the supply air temperature (see above). Since the majority of circular temperature charts record the return air temperature (see above) the manually recorded data for a container in low-temperature mode should be the same as is recorded on the circular chart. In chilled mode on the other hand it is possible (and normal) that there are differences between the return air recordings made by hand and the supply air temperature registered by the recorder.



Position	Serial	POD	POL	Temp	24.6	25.6.	26.6.	27.6.	28.6.	29.6.	30.6.
15 10 82	KNLU2753895	SYD	HAM	3.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
15 06 82	TRLU1001098	SYD	HAM	3.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
15 05 82	POCU2817785	ARL	TIL	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
15 07 82	KNLU2788164	ARL	RTM	-1.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
15 07 84	POCU2846982	ARL	RTM	20.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
15 09 82	HLCU1700880	ARL	RTM	20.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 06 82	AJCU2922114	MEL	RTM	12.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 06 84	POCU2820274	MEL	RTM	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 04 82	HLCU2711386	MEL	RTM	16.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 04 84	POCU2942191	MEL	RTM	16.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 02 82	TRIU6480065	MEL	HAM	2.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 02 84	KNLU2773401	MEL	HAM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 00 84	POCU2805827	MEL	RTM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 01 84	KNLU2789199	MEL	RTM	3.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 03 82	POCU2840218	MEL	RTM	16.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 03 84	POCU2818071	MEL	RTM	1.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 05 82	POCU2822281	MEL	RTM	18.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 05 84	KNLU2782848	MEL	RTM	1.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 07 82	KNLU2719442	MEL	RTM	17.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
17 07 84	KNLU2782577	MEL	RTM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 04 82	KNLU2779583	MEL	RTM	-18.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 04 84	HLCU2711578	MEL	RTM	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 02 82	KNLU2778384	MEL	HAM	3.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 02 84	KNLU2786097	MEL	HAM	-20.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 00 82	GCEU2015615	MEL	HAM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 00 84	CRXU5724497	MEL	HAM	12.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 03 82	POCU2805641	MEL	RTM	-18.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 05 84	HLCU2707112	MEL	RTM	12.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 07 82	POCU2808978	MEL	RTM	18.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
19 07 84	LPIU5055065	MEL	RTM	16.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 10 82	KNLU2781374	SYD	HAM	3.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 08 82	GCEU2954578	SYD	HAM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 06 84	POCU2825342	SYD	HAM	9.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 06 82	GCEU2000182	SYD	HAM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 06 84	HLXU2700520	SYD	HAM	12.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 05 82	ACTU8001439	SYD	TIL	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 05 84	LPIU5720957	SYD	TIL	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 07 82	AJCU2930974	SYD	TIL	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 07 84	KNLU2773572	SYD	TIL	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
21 09 82	POCU2818132	SYD	TIL	15.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 10 82	KNLU2788358	SYD	HAM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 08 82	TRLU1007199	SYD	HAM	-19.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 08 84	POCU2835232	SYD	HAM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 05 82	TRLU1033014	SYD	HAM	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 08 84	KNLU2759738	SYD	HAM	6.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 04 82	LPIU5711359	SYD	SPE	11.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 02 82	TRIU6720696	SYD	SPE	11.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 00 82	PONU2854909	SYD	SPE	11.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
23 01 82	POCU2813479	SYD	SPE	11.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
25 02 82	POCU2810867	MEL	TIL	12.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
25 00 82	POCU2847254	MEL	TIL	24.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
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27 10 82	TRIU6457511	MEL	SPE	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
27 08 82	POCU2870090	MEL	SPE	4.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
27 08 82	ICSU5505533	MEL	SPE	5.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

Figure 42: Manually completed temperature log of a vessel

(Click the graphic to enlarge.)

8.4.2.2.5 Remote monitoring

Since daily inspection of the large numbers of refrigerated containers carried on board a vessel takes a significant time, a number of shipping companies have started to use systems which enable remote monitoring of the containers. Data is exchanged between the ship's computer and the containers over the power cable of the containers. This includes information about current temperatures, any alarms that have occurred etc. The printed logs that are generated as a result of this exchange can effectively replace manually recorded temperature data.

In addition, the crew is in a position to react to problems more quickly, since when relying on daily rounds it is possible that a container has had an alarm flagged for 24 hours before this is noticed.

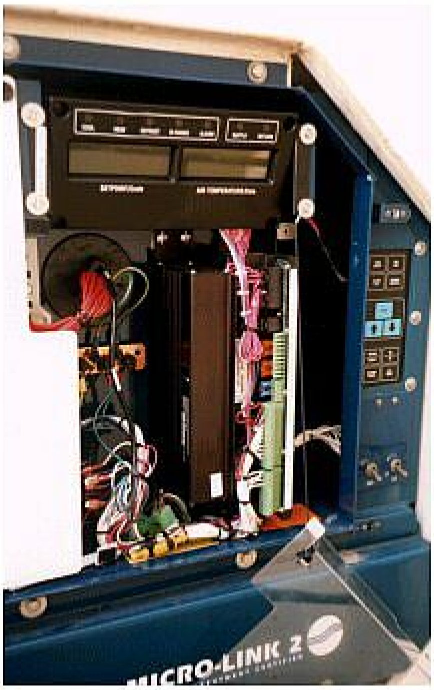


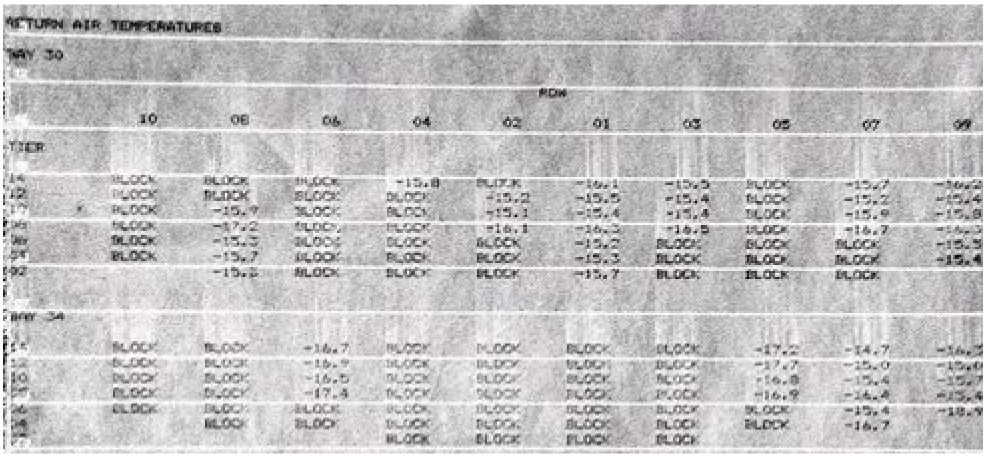
Figure 43: Remote monitoring modem in a refrigeration unit

8.4.2.2.6 Conair or porthole containers

Conair or porthole refrigerated containers that do not have their own refrigeration unit are usually supplied with cold air by refrigeration units installed in the vessel or by clip-on refrigeration units. The clip-on units usually have their own temperature recorders that use normal circular temperature charts whereas the refrigeration units installed on the vessel are usually monitored by a central system. This generates printouts at given intervals, usually every four

hours, showing the supply and return air temperatures of all the connected containers. Figure 45 shows an example of a printout of this type. The containers are identified according to their stowage locations in the vessel. Often used in conjunction with a log printer for recording the temperatures, an alarm printer is also available which prints alarms and any failures of the refrigeration system.

Figure 44: Conair refrigeration system on a vessel



RETURN AIR TEMPERATURES

BAY 30

TIER	ROW 10	08	06	04	02	01	03	05	07	09
14	BLOCK	BLOCK	BLOCK	-15.8	BLOCK	-16.1	-15.5	BLOCK	-15.7	-16.2
12	BLOCK	BLOCK	BLOCK	BLOCK	-15.2	-15.5	-15.4	BLOCK	-15.2	-15.4
[illegible]	BLOCK	-15.9	BLOCK	BLOCK	-15.1	-15.4	-15.4	BLOCK	-15.9	-15.8
[illegible]	BLOCK	-17.2	BLOCK	BLOCK	-16.1	-16.3	-16.5	BLOCK	-16.7	[illegible]
[illegible]	BLOCK	-15.3	BLOCK	BLOCK	BLOCK	-15.2	BLOCK	BLOCK	BLOCK	-15.5
[illegible]	BLOCK	-15.7	BLOCK	BLOCK	BLOCK	-15.3	BLOCK	BLOCK	BLOCK	-15.4
02		-15.2	BLOCK	BLOCK	BLOCK	-15.7	BLOCK	BLOCK	BLOCK	

BAY 34

TIER	10	08	06	04	02	01	03	05	07	09
14	BLOCK	BLOCK	-16.7	BLOCK	BLOCK	BLOCK	BLOCK	-17.2	-14.7	-16.3
12	BLOCK	BLOCK	-16.9	BLOCK	BLOCK	BLOCK	BLOCK	-17.7	-15.0	-15.0
10	BLOCK	BLOCK	-16.5	BLOCK	BLOCK	BLOCK	BLOCK	-16.8	-15.4	-15.7
[illegible]	BLOCK	BLOCK	-17.4	BLOCK	BLOCK	BLOCK	BLOCK	-16.9	-14.4	-15.4
[illegible]	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	-15.4	-18.9
[illegible]		BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	BLOCK	-16.7	
[illegible]				BLOCK	BLOCK	BLOCK	BLOCK			

Figure 45: Example of a temperature printout of a Conair container refrigeration system on a vessel

8.4.2.3 Influence of the stowage methods on the return air temperature

Whereas the supply air temperature provides information about whether the refrigeration unit is working, the return air temperature allows conclusions to be drawn about the temperature of the cargo. The prerequisite for this is that the air actually flows through the cargo and takes on the temperature of the cargo.

Unfortunately the method used to stow the goods in the container often does not allow this to happen. Typical stowage errors can be seen in figure 46. These include in particular the circulation bypasses as shown in the three examples at the top, or interruptions of flow as caused by the cargo being stowed too densely, exceeding the maximum stowage height and the use of covers, among other things, as shown in the bottom examples.

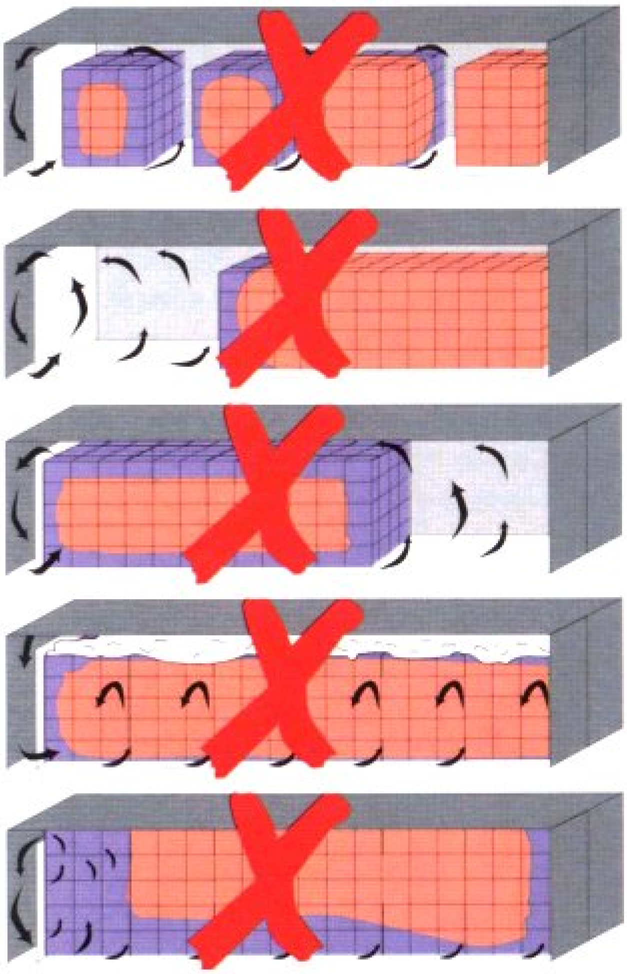


Figure 46:
Stowage methods
in refrigerated containers that
may lead to poor temperature distribution within
the cargo and should thus be avoided

Other faults are also possible in addition to the ones shown in Figure 46. An evenly distributed, but loosely packed cargo with a number of small circulation bypasses can also mean that no cold air circulates at the rear of the container (at the door).

The information that the return air temperature offers with respect to the temperature of the cargo will thus depend largely on the way in which the cargo has been stowed in the container. If there are serious circulation bypasses, the return air temperature will be very close to the supply air temperature. If the airflow through the cargo is good, the return air temperature will be very close to the temperature of the cargo.

Since the air that flows through the cargo space must always remove the heat coming from outside the container as well as any heat caused by ripening or cooling processes, the return air temperature should usually be higher than the supply air temperature where the cargo temperature is being maintained. As a general rule of thumb, approximately 500 W of heat enters a 40' container for each 10°C difference in temperature compared with the ambient temperature. When operating in low-temperature mode with a 40-fold circulation of air, this leads to a temperature increase of approximately 0.6°C over the supply air temperature, when operating in chilled mode with an 80-fold circulation of air, the increase is approximately 0.3°C. With greater differences in temperature compared to the ambient temperature, this value increases accordingly, and a temperature increase of approximately 3°C can thus be expected for a 50°C temperature difference (inside -20°C, outside +30°C). Since the circulating air exchanges heat with the cargo this is also the range in which the cargo temperature may normally vary according to the location of the cargo within the container.

However, if there are areas within the container in which no air or very little air is able to circulate, these areas may experience considerable increases in temperature. An example of such a case is shown in Figure 47.

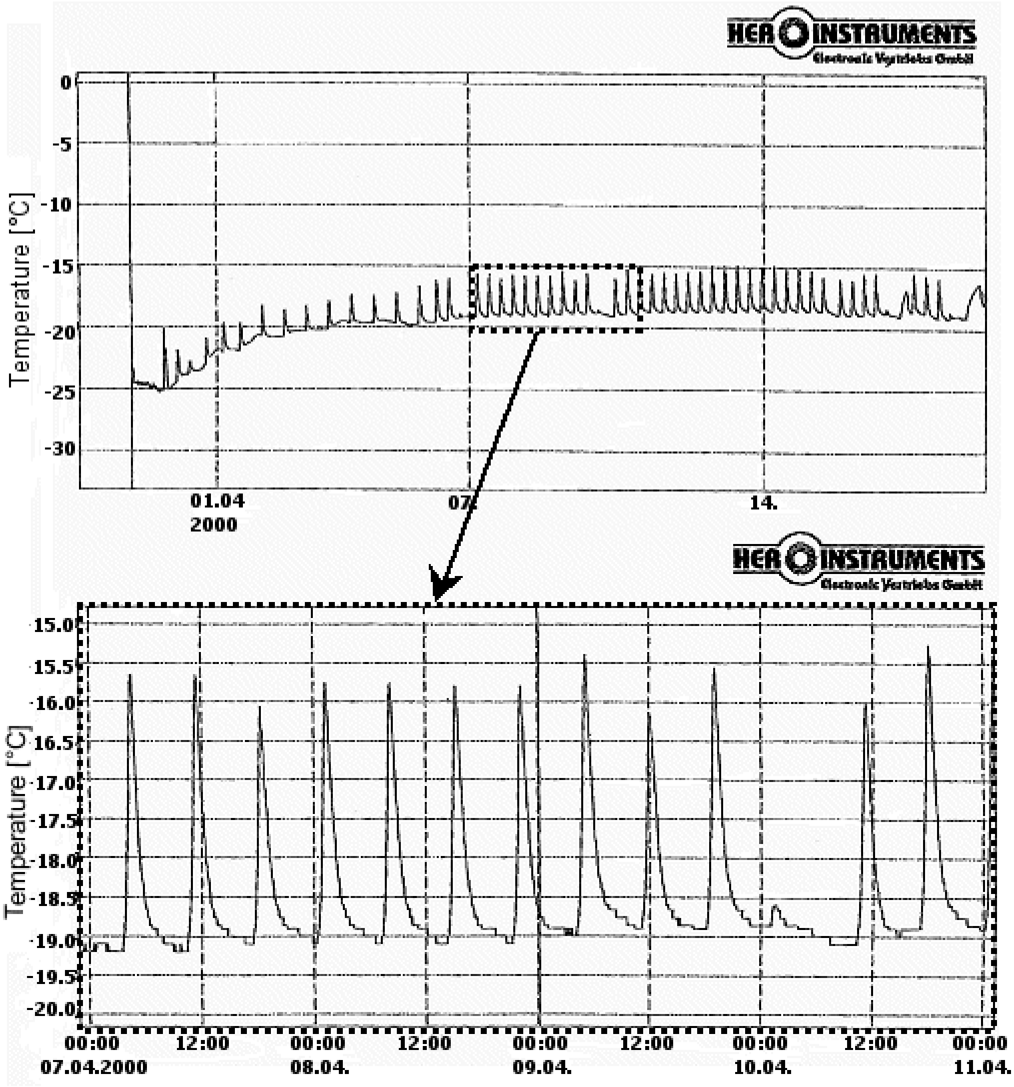


Figure 47: Example of temperature increase at the door as a result of incorrect stowage and the lower level of air circulation caused by this
(for the entire duration of the journey and an enlarged extract)

The goods were loaded into the container at a temperature of -25°C. This is also the nominal temperature value. The supply air temperature was at -26°C during the entire transport, the return air temperature was at -24°C. This data was recorded by the data logger of the container. An electronic data logger was placed on the last pallet in the container. The data from this data logger is shown in figure 47. At the start of the journey the temperature was as required at -25°C. It rose to -19°C over a period of approximately six days. This temperature was then maintained. This behavior suggests that in the area where the data logger was placed, the circulating volume of air was not sufficient to completely remove the heat coming from outside and maintain the temperature at -25°C. Only at -19°C was an equilibrium achieved. The enlarged section of the temperature chart makes this very clear. Since the data logger was located on top of the cargo, the defrosting processes were registered very quickly since a layer of warm air formed at the top of the container.

Once the refrigeration process was started again the temperature sank slowly back to the equilibrium temperature of -19°C. If the flow of air had been sufficient around the data logger, the temperature at the end of the defrosting cycle would have sunk just as fast as it rose. Since this was not the case, we can conclude that this area of the container was subject to very little air circulation. However, the temperature recordings do not reveal whether the low air flow was caused by interruption of the flow by stowing the cargo too densely at the door or by a circulation bypass in the front part of the container. The only way of determining this is from surveyor reports which show the way in which the cargo was stowed in the container.

8.4.3 Temperature changes within the container

8.4.3.1 Temperature increases without refrigeration

8.4.3.1.1 Calculating the increase in temperature

8.4.3.1.2 Numeric calculation of the increase in temperature

→ 8.4.3.2 Cooling of the cargo during refrigeration

8.4.3.1 Temperature increases without refrigeration

In order to evaluate temperature records, it is often critical to estimate the extent to which temperature changes are actually physically possible for the goods in the container over time. It is often the case that the refrigerated container is not cooled for a period of time. This happens regularly when transshipping containers from ship to shore etc. but may also occur as a result of a technical fault. The temperature increase in a container without refrigeration will therefore be described briefly at this point.

8.4.3.1.1 Rule of thumb calculation for the temperature increase

For a rule of thumb calculation of the increase in temperature of the cargo in the container, it is assumed that the entire cargo increases in temperature at the same rate without the formation of any local temperature differences. A calculation of this nature therefore does not take into account in particular the temperature layering that occurs in a container as a result of long periods of standstill.

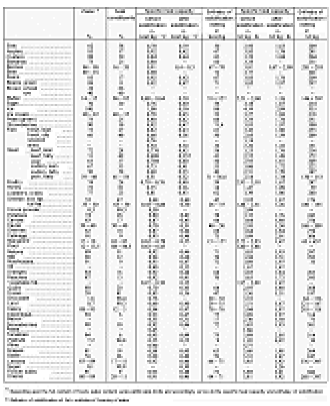
For the temperature increase over time t, the following equation applies for non-respiring goods (goods with no respiration heat)

$$\Delta T(t) = \Delta T_{ambient} - \Delta T_{ambient} \cdot e^{-\frac{A \cdot k}{m \cdot c_p} \cdot t}$$

where t:	Is time without refrigeration (in s)
ΔT:	Average increase in temperature of the load after time t (in°C)
$\Delta T_{ambient}$:	Difference in temperature between the internal and external temperatures at the start of the warming process (in°C)
A:	Surface area of the container (in m²)
k	Heat transition coefficient of the container in (in W/m²K)
m	Mass of the load (in kg)
c_p:	Specific heat capacity of the load (in J/kgK), see Table 13

The heat transition coefficient of the container can be taken to be 0.4 W/m²K. In accordance with the ATP agreement, new containers must fulfill this value in order to be granted a permit for use in cross-border transportation. New containers generally achieve values of approximately 0.3 W/m²K, but the insulation is subject to ageing.

Since the majority of frozen goods are made up mainly of water, some with more and some with less fat content, the heat capacity lies between 1.1 and 2.1 kJ/kgK, and for the majority of goods an average value of approximately 1.7 kJ/kgK can be assumed (see Table 13). In an unfrozen state the heat capacity is approximately twice as high, and thus the increase in temperature will take longer.



(Click on the graphic to enlarge.)

Table 13:
Specific heat capacities of various foodstuffs, taken from Pohlmann, Taschenbuch der Kältetechnik
(Ready reference of refrigeration technology)

Table 14 (made up of eight individual tables) gives, for a typical refrigerated container, the average temperature increase of the load depending on container type, cargo mass, and the difference in temperature compared to the ambient temperature. These values can be used to perform rule of thumb estimations for the temperature increase.

20 ft Container
Average temperature increase after 12 hours

		Temperature difference, internal vs. ambient							
		5 K	**10 K**	**15 K**	**20 K**	**25 K**	**30 K**	**35 K**	**40 K**
Cargo mass	**5 t**	0.7 K	1.3 K	2.0 K	2.7 K	3.3 K	4.0 K	4.6 K	5.3 K
	6 t	0.6 K	1.1 K	1.7 K	2.2 K	2.8 K	3.4 K	3.9 K	4.5 K
	7 t	0.5 K	1.0 K	1.4 K	1.9 K	2.4 K	2.9 K	3.4 K	3.9 K
	8 t	0.4 K	0.9 K	1.3 K	1.7 K	2.1 K	2.6 K	3.0 K	3.4 K
	9 t	0.4 K	0.8 K	1.1 K	1.5 K	1.9 K	2.3 K	2.7 K	3.0 K
	10 t	0.3 K	0.7 K	1.0 K	1.4 K	1.7 K	2.1 K	2.4 K	2.7 K
	11 t	0.3 K	0.6 K	0.9 K	1.3 K	1.6 K	1.9 K	2.2 K	2.5 K
	12 t	0.3 K	0.6 K	0.9 K	1.2 K	1.4 K	1.7 K	2.0 K	2.3 K
	13 t	0.3 K	0.5 K	0.8 K	1.1 K	1.3 K	1.6 K	1.9 K	2.1 K
	14 t	0.2 K	0.5 K	0.7 K	1.0 K	1.2 K	1.5 K	1.7 K	2.0 K
	15 t	0.2 K	0.5 K	0.7 K	0.9 K	1.2 K	1.4 K	1.6 K	1.9 K
	16 t	0.2 K	0.4 K	0.7 K	0.9 K	1.1 K	1.3 K	1.5 K	1.7 K
	17 t	0.2 K	0.4 K	0.6 K	0.8 K	1.0 K	1.2 K	1.4 K	1.6 K
	18 t	0.2 K	0.4 K	0.6 K	0.8 K	1.0 K	1.2 K	1.4 K	1.6 K
	19 t	0.2 K	0.4 K	0.6 K	0.7 K	0.9 K	1.1 K	1.3 K	1.5 K
	20 t	0.2 K	0.3 K	0.5 K	0.7 K	0.9 K	1.0 K	1.2 K	1.4 K

20 ft Container
Average temperature increase after 24 hours

		Temperature difference, internal vs. ambient							
		5 K	**10 K**	**15 K**	**20 K**	**25 K**	**30 K**	**35 K**	**40 K**
Cargo mass	**5 t**	1.2 K	2.5 K	3.7 K	5.0 K	6.2 K	7.4 K	8.7 K	9.9 K
	6 t	1.1 K	2.1 K	3.2 K	4.2 K	5.3 K	6.3 K	7.4 K	8.4 K
	7 t	0.9 K	1.8 K	2.8 K	3.7 K	4.6 K	5.5 K	6.4 K	7.4 K
	8 t	0.8 K	1.6 K	2.4 K	3.3 K	4.1 K	4.9 K	5.7 K	6.5 K
	9 t	0.7 K	1.5 K	2.2 K	2.9 K	3.7 K	4.4 K	5.1 K	5.9 K
	10 t	0.7 K	1.3 K	2.0 K	2.7 K	3.3 K	4.0 K	4.6 K	5.3 K
	11 t	0.6 K	1.2 K	1.8 K	2.4 K	3.0 K	3.6 K	4.2 K	4.9 K
	12 t	0.6 K	1.1 K	1.7 K	2.2 K	2.8 K	3.4 K	3.9 K	4.5 K
	13 t	0.5 K	1.0 K	1.6 K	2.1 K	2.6 K	3.1 K	3.6 K	4.1 K
	14 t	0.5 K	1.0 K	1.4 K	1.9 K	2.4 K	2.9 K	3.4 K	3.9 K
	15 t	0.5 K	0.9 K	1.4 K	1.8 K	2.3 K	2.7 K	3.2 K	3.6 K
	16 t	0.4 K	0.9 K	1.3 K	1.7 K	2.1 K	2.6 K	3.0 K	3.4 K
	17 t	0.4 K	0.8 K	1.2 K	1.6 K	2.0 K	2.4 K	2.8 K	3.2 K
	18 t	0.4 K	0.8 K	1.1 K	1.5 K	1.9 K	2.3 K	2.7 K	3.0 K
	19 t	0.4 K	0.7 K	1.1 K	1.4 K	1.8 K	2.2 K	2.5 K	2.9 K
	20 t	0.3 K	0.7 K	1.0 K	1.4 K	1.7 K	2.1 K	2.4 K	2.7 K

20 ft Container
Average temperature increase after 48 hours

		Temperature difference, internal vs. ambient							
		5 K	**10 K**	**15 K**	**20 K**	**25 K**	**30 K**	**35 K**	**40 K**
Cargo mass	**5 t**	2.2 K	4.3 K	6.5 K	8.7 K	10.9 K	13.0 K	15.2 K	17.4 K
	6 t	1.9 K	3.8 K	5.7 K	7.6 K	9.4 K	11.3 K	13.2 K	15.1 K
	7 t	1.7 K	3.3 K	5.0 K	6.7 K	8.4 K	10.0 K	11.7 K	13.4 K
	8 t	1.5 K	3.0 K	4.5 K	6.0 K	7.5 K	9.0 K	10.5 K	12.0 K
	9 t	1.4 K	2.7 K	4.1 K	5.4 K	6.8 K	8.1 K	9.5 K	10.8 K
	10 t	1.2 K	2.5 K	3.7 K	5.0 K	6.2 K	7.4 K	8.7 K	9.9 K
	11 t	1.1 K	2.3 K	3.4 K	4.6 K	5.7 K	6.8 K	8.0 K	9.1 K
	12 t	1.1 K	2.1 K	3.2 K	4.2 K	5.3 K	6.3 K	7.4 K	8.4 K
	13 t	1.0 K	2.0 K	2.9 K	3.9 K	4.9 K	5.9 K	6.9 K	7.9 K
	14 t	0.9 K	1.8 K	2.8 K	3.7 K	4.6 K	5.5 K	6.4 K	7.4 K
	15 t	0.9 K	1.7 K	2.6 K	3.5 K	4.3 K	5.2 K	6.0 K	6.9 K
	16 t	0.8 K	1.6 K	2.4 K	3.3 K	4.1 K	4.9 K	5.7 K	6.5 K
	17 t	0.8 K	1.5 K	2.3 K	3 1 K	3.9 K	4.6 K	5.4 K	6.2 K
	18 t	0.7 K	1.5 K	2.2 K	2.9 K	3.7 K	4.4 K	5.1 K	5.9 K
	19 t	0.7 K	1.4 K	2.1 K	2.8 K	3.5 K	4.2 K	4.9 K	5.6 K
	20 t	0.7 K	1.3 K	2.0 K	2.7 K	3.3 K	4.0 K	4.6 K	5.3 K

20 ft Container
Average temperature increase after 72 hours

		Temperature difference, internal vs. ambient							
		5 K	**10 K**	**15 K**	**20 K**	**25 K**	**30 K**	**35 K**	**40 K**
Cargo mass	**5 t**	2.9 K	5.7 K	8.6 K	11.5 K	14.4 K	17.2 K	20.1 K	23.0 K
	6 t	2.5 K	5.1 K	7.6 K	10.2 K	12.7 K	15.3 K	17.8 K	20.4 K
	7 t	2.3 K	4.6 K	6.8 K	9.1 K	11.4 K	13.7 K	16.0 K	18.3 K
	8 t	2.1 K	4.1 K	6.2 K	8.3 K	10.3 K	12.4 K	14.5 K	16.5 K
	9 t	1.9 K	3.8 K	5.7 K	7.6 K	9.4 K	11.3 K	13.2 K	15.1 K
	10 t	1.7 K	3.5 K	5.2 K	6.9 K	8.7 K	10.4 K	12.2 K	13.9 K
	11 t	1.6 K	3.2 K	4.8 K	6.4 K	8.0 K	9.6 K	11.3 K	12.9 K
	12 t	1.5 K	3.0 K	4.5 K	6.0 K	7.5 K	9.0 K	10.5 K	12.0 K
	13 t	1.4 K	2.8 K	4.2 K	5.6 K	7.0 K	8.4 K	9.8 K	11.2 K
	14 t	1.3 K	2.6 K	3.9 K	5.3 K	6.6 K	7.9 K	9.2 K	10.5 K
	15 t	1.2 K	2.5 K	3.7 K	5.0 K	6.2 K	7.4 K	8.7 K	9.9 K
	16 t	1.2 K	2.3 K	3.5 K	4.7 K	5.9 K	7.0 K	8.2 K	9.4 K
	17 t	1.1 K	2.2 K	3.3 K	4.4 K	5.6 K	6.7 K	7.8 K	8.9 K
	18 t	1.1 K	2.1 K	3.2 K	4.2 K	5.3 K	6.3 K	7.4 K	8.4 K
	19 t	1.0 K	2.0 K	3.0 K	4.0 K	5.0 K	6.0 K	7.0 K	8.0 K
	20 t	1.0 K	1.9 K	2.9 K	3.8 K	4.8 K	5.8 K	6.7 K	7.7 K

40 ft Container
Average Temperature increase after 12 hours

		Temperature difference, internal vs. ambient							
		5 K	**10 K**	**15 K**	**20 K**	**25 K**	**30 K**	**35 K**	**40 K**
Cargo mass	**5 t**	1.2 K	2.4 K	3.5 K	4.7 K	5.9 K	7.1 K	8.2 K	9.4 K
	6 t	1.0 K	2.0 K	3.0 K	4.0 K	5.0 K	6.0 K	7.0 K	8.0 K
	7 t	0.9 K	1.7 K	2.6 K	3.5 K	4.4 K	5.2 K	6.1 K	7.0 K
	8 t	0.8 K	1.5 K	2.3 K	3.1 K	3.9 K	4.6 K	5.4 K	6.2 K
	9 t	0.7 K	1.4 K	2.1 K	2.8 K	3.5 K	4.2 K	4.8 K	5.5 K
	10 t	0.6 K	1.3 K	1.9 K	2.5 K	3.1 K	3.8 K	4.4 K	5.0 K
	11 t	0.6 K	1.1 K	1.7 K	2.3 K	2.9 K	3.4 K	4.0 K	4.6 K
	12 t	0.5 K	1.1 K	1.6 K	2.1 K	2.6 K	3.2 K	3.7 K	4.2 K
	13 t	0.5 K	1.0 K	1.5 K	2.0 K	2.5 K	2.9 K	3.4 K	3.9 K
	14 t	0.5 K	0.9 K	1.4 K	1.8 K	2.3 K	2.7 K	3.2 K	3.7 K
	15 t	0.4 K	0.9 K	1.3 K	1.7 K	2.1 K	2.6 K	3.0 K	3.4 K
	16 t	0.4 K	0.8 K	1.2 K	1.6 K	2.0 K	2.4 K	2.8 K	3.2 K
	17 t	0.4 K	0.8 K	1.1 K	1.5 K	1.9 K	2.3 K	2.7 K	3.0 K
	18 t	0.4 K	0.7 K	1.1 K	1.4 K	1.8 K	2.2 K	2.5 K	2.9 K
	19 t	0.3 K	0.7 K	1.0 K	1.4 K	1.7 K	2.0 K	2.4 K	2.7 K
	20 t	0.3 K	0.6 K	1.0 K	1.3 K	1.6 K	1.9 K	2.3 K	2.6 K

40 ft Container
Average Temperature increase after 24 hours

		Temperature difference, internal vs. ambient							
		5 K	**10 K**	**15 K**	**20 K**	**25 K**	**30 K**	**35 K**	**40 K**
Cargo mass	**5 t**	2.1 K	4.2 K	6.2 K	8.3 K	10.4 K	12.5 K	14.5 K	16.6 K
	6 t	1.8 K	3.6 K	5.4 K	7.2 K	9.0 K	10.8 K	12.6 K	14.4 K
	7 t	1.6 K	3.2 K	4.8 K	6.4 K	8.0 K	9.6 K	11.1 K	12.7 K
	8 t	1.4 K	2.8 K	4.3 K	5.7 K	7.1 K	8.5 K	10.0 K	11.4 K
	9 t	1.3 K	2.6 K	3.9 K	5.2 K	6.4 K	7.7 K	9.0 K	10.3 K
	10 t	1.2 K	2.4 K	3.5 K	4.7 K	5.9 K	7.1 K	8.2 K	9.4 K
	11 t	1.1 K	2.2 K	3.2 K	4.3 K	5.4 K	6.5 K	7.6 K	8.7 K
	12 t	1.0 K	2.0 K	3.0 K	4.0 K	5.0 K	6.0 K	7.0 K	8.0 K
	13 t	0.9 K	1.9 K	2.8 K	3.7 K	4.7 K	5.6 K	6.5 K	7.5 K
	14 t	0.9 K	1.7 K	2.6 K	3.5 K	4.4 K	5.2 K	6.1 K	7.0 K
	15 t	0.8 K	1.6 K	2.5 K	3.3 K	4.1 K	4.9 K	5.7 K	6.6 K
	16 t	0.8 K	1.5 K	2.3 K	3.1 K	3.9 K	4.6 K	5.4 K	6.2 K
	17 t	0.7 K	1.5 K	2.2 K	2.9 K	3.7 K	4.4 K	5.1 K	5.8 K
	18 t	0.7 K	1.4 K	2.1 K	2.8 K	3.5 K	4.2 K	4.8 K	5.5 K
	19 t	0.7 K	1.3 K	2.0 K	2.6 K	3.3 K	4.0 K	4.6 K	5.3 K
	20 t	0.6 K	1.3 K	1.9 K	2.5 K	3.1 K	3.8 K	4.4 K	5.0 K

40 ft Container Average temperature increase after 48 hours									
		Temperature difference, internal vs. ambient							
		5 K	10 K	15 K	20 K	25 K	30 K	35 K	40 K
Cargo mass	5 t	3.3 K	6.6 K	9.9 K	13.2 K	16.5 K	19.7 K	23.0 K	26.3 K
	6 t	3.0 K	5.9 K	8.9 K	11.8 K	14.8 K	17.7 K	20.7 K	23.6 K
	7 t	2.7 K	5.4 K	8.0 K	10.7 K	13.4 K	16.1 K	18.7 K	21.4 K
	8 t	2.4 K	4.9 K	7.3 K	9.8 K	12.2 K	14.7 K	17.1 K	19.5 K
	9 t	2.2 K	4.5 K	6.7 K	9.0 K	11.2 K	13.5 K	15.7 K	18.0 K
	10 t	2.1 K	4.2 K	6.2 K	8.3 K	10.4 K	12.5 K	14.5 K	16.6 K
	11 t	1.9 K	3.9 K	5.8 K	7.7 K	9.7 K	11.6 K	13.5 K	15.4 K
	12 t	1.8 K	3.6 K	5.4 K	7.2 K	9.0 K	10.8 K	12.6 K	14.4 K
	13 t	1.7 K	3.4 K	5.1 K	6.8 K	8.5 K	10.1 K	11.8 K	13.5 K
	14 t	1.6 K	3.2 K	4.8 K	6.4 K	8.0 K	9.6 K	11.1 K	12.7 K
	15 t	1.5 K	3.0 K	4.5 K	6.0 K	7.5 K	9.0 K	10.5 K	12.0 K
	16 t	1.4 K	2.8 K	4.3 K	5.7 K	7.1 K	8.5 K	10.0 K	11.4 K
	17 t	1.4 K	2.7 K	4.1 K	5.4 K	6.8 K	8.1 K	9.5 K	10.8 K
	18 t	1.3 K	2.6 K	3.9 K	5.2 K	6.4 K	7.7 K	9.0 K	10.3 K
	19 t	1.2 K	2.5 K	3.7 K	4.9 K	6.2 K	7.4 K	8.6 K	9.8 K
	20 t	1.2 K	2.4 K	3.5 K	4.7 K	5.9 K	7.1 K	8.2 K	9.4 K

40 ft Container Average temperature increase after 72 hours									
		Temperature difference, internal vs. ambient							
		5 K	10 K	15 K	20 K	25 K	30 K	35 K	40 K
Cargo mass	5 t	4.0 K	8.0 K	12.0 K	16.0 K	20.0 K	24.0 K	28.0 K	32.0 K
	6 t	3.7 K	7.4 K	11.1 K	14.8 K	18.5 K	22.2 K	25.9 K	29.5 K
	7 t	3.4 K	6.8 K	10.3 K	13.7 K	17.1 K	20.5 K	23.9 K	27.3 K
	8 t	3.2 K	6.3 K	9.5 K	12.7 K	15.9 K	19.0 K	22.2 K	25.4 K
	9 t	3.0 K	5.9 K	8.9 K	11.8 K	14.8 K	17.7 K	20.7 K	23.6 K
	10 t	2.8 K	5.5 K	8.3 K	11.1 K	13.8 K	16.6 K	19.4 K	22.1 K
	11 t	2.6 K	5.2 K	7.8 K	10.4 K	13.0 K	15.6 K	18.2 K	20.8 K
	12 t	2.4 K	4.9 K	7.3 K	9.8 K	12.2 K	14.7 K	17.1 K	19.5 K
	13 t	2.3 K	4.6 K	6.9 K	9.2 K	11.5 K	13.8 K	16.2 K	18.5 K
	14 t	2.2 K	4.4 K	6.6 K	8.7 K	10.9 K	13.1 K	15.3 K	17.5 K
	15 t	2.1 K	4.2 K	6.2 K	8.3 K	10.4 K	12.5 K	14.5 K	16.6 K
	16 t	2.0 K	4.0 K	5.9 K	7.9 K	9.9 K	11.9 K	13.8 K	15.8 K
	17 t	1.9 K	3.8 K	5.7 K	7.5 K	9.4 K	11.3 K	13.2 K	15.1 K
	18 t	1.8 K	3.6 K	5.4 K	7.2 K	9.0 K	10.8 K	12.6 K	14.4 K
	19 t	1.7 K	3.5 K	5.2 K	6.9 K	8.6 K	10.4 K	12.1 K	13.8 K
	20 t	1.7 K	3.3 K	5.0 K	6.6 K	8.3 K	9.9 K	11.6 K	13.3 K

Table 14: Average increase in temperature of the load for various container sizes, valid for frozen goods

Example:

A 20' container with a load of 20 t meat and an initial temperature of -20°C is not refrigerated for a period of two days. The ambient temperature is 20°C. This gives a difference in temperature of 40°C, and from table 14, we obtain an average temperature increase of 5.3°C. Thus the temperature of the meat rises, on average, to -14.7°C.

8.4.3.1.2 Numeric calculation of the increase in temperature

In order to be able to determine the influence of temperature distribution in the cargo, it is necessary to perform a numeric simulation of the increase in temperature. To do this, a container and its cargo is divided into a number of individual elements, and the rise in temperature is determined for each of the elements over a given period of time. The new temperatures calculated in this manner are used to determine the heat exchange with the environment through the insulation of the container or with the neighboring elements. This in turn allows a new temperature change to be calculated. This process is repeated until the entire observation period has been calculated.

The simulation carried out here used a 20' container divided into 10 x 25 x 10 elements, with each element being a cube with an edge length of approximately 24 cm. The period of time for each calculation step was 60 seconds. The simulation made the assumptions described in the example for rule of thumb calculations given above.

The results of this calculation are shown in the following figures for 12 hours, 24 hours and 48 hours without refrigeration. The average increase in temperature after 48 hours is 5.2 K and is thus just below the figure calculated using the rule of thumb. This effect comes from the fact that rapid warming of the outer layers of the load reduces the temperature difference to the environment thus less heat enters through the insulation.

It can be clearly seen that the most exposed locations in the container increase in temperature most rapidly. These are

the top corners of the container. After 12 hours, the increase in temperature here is already 7.0 K, after 24 hours it is 9.2 K, and after 48 hours it is as much as 13.1 K. At the same time the core of the load has increased in temperature by just 1.6 K even after 48 hours.

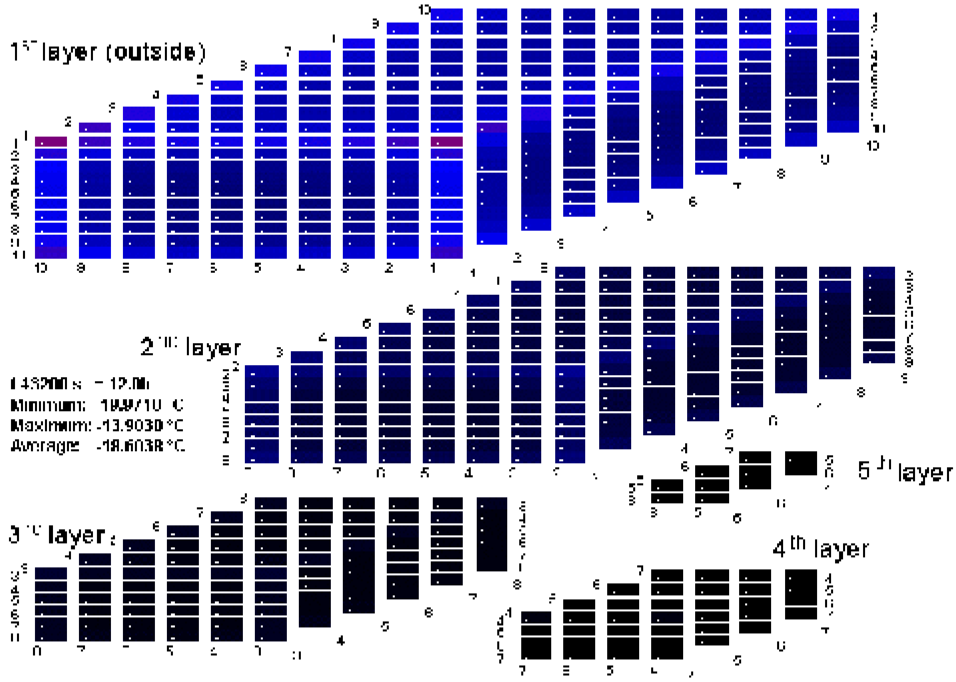


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Figure 48: Calculated temperature distribution in the container after 12 hours; initial internal temperature -20°C, external temperature +20°C

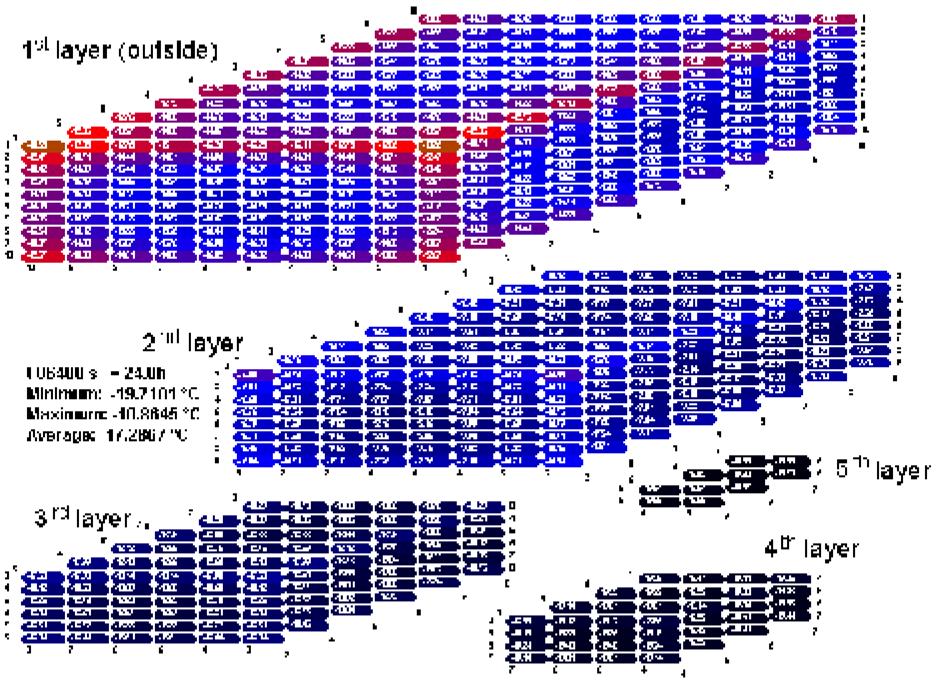

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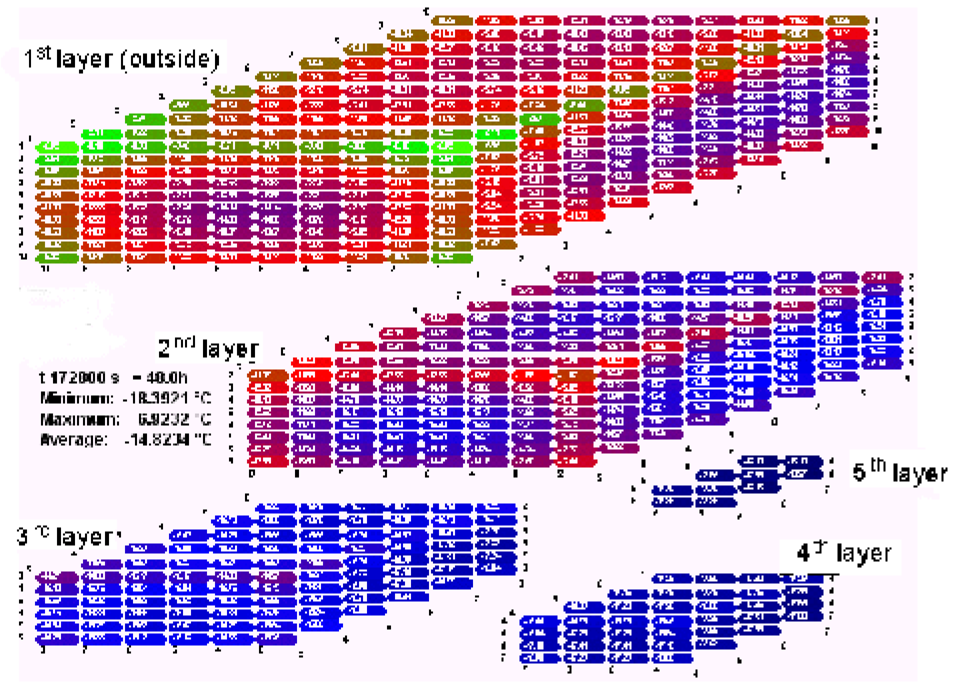
Figure 49: Calculated temperature distribution in the container after 24 hours; initial internal temperature -20°C, external temperature +20°C



Click on graphic to enlarge.

Figure 50: Calculated temperature distribution in the container after 48 hours; initial internal temperature -20°C, external temperature +20°C

The precise degree to which the temperature of the top corners of the stowed goods increase compared with the average temperature rise will depend very much on the thermal conductivity of the block of goods. The following principle applies: The greater the stowage density of the goods, the more uniformly the temperature of the goods increases. This is because a low stowage density indicates that there is a higher proportion of air in the packaging since the actual density of the goods is almost always the same because of their high water content. The air contained in the packaging acts as an insulator which hinders the transfer of heat from the outer layers to the inner layers.

Generally this calculation indicates clearly that even a relatively short absence of the refrigeration system, for example, a single day, can lead to significantly increased temperatures in the exposed sections of the load. Thus if data loggers are used in the cargo it is of great importance where in the container they are located.

8.4.3.2 Cooling of the cargo during refrigeration

The cargo in the container can also be cooled with continuous refrigeration. The time it takes to cool the cargo depends on the heat transfer between the cargo and the air as well as the refrigeration capacity that is available.

A modern refrigeration unit has a refrigeration capacity of approximately 5 to 6 kW in low-temperature operation at -18°C. Depending on the container type being used (20' / 40'), 1.5 kW through 2.6 kW will be required in order to remove the heat that enters through the insulation. This leaves approximately 2.4 to 4.5 kW that can be used to cool the cargo.

The following applies:

$$Q_{average} = \frac{m \cdot c_p \cdot \Delta T}{t}$$

in which

$Q_{average}$: Average refrigerating capacity for cooling the cargo (in W)

t: Time in which cooling should take place (in s)

ΔT: Cargo temperature change after time t (in K)

m: Mass of cargo (in kg)

c_p: Specific heat capacity of cargo (in J/kg/K) see Table 13

If the refrigeration capacity is known, the maximum cooling speed can be determined. If a refrigeration capacity of 4 kW is available for cooling (see above) then it would be possible to cool, for example, 10 tons of frozen meat by roughly 1.1°C per hour.

This maximum cooling speed is usually not achieved since the heat transferred from the goods to the air is less then the refrigeration capacity. This is particularly relevant for frozen cargo and cargo containing non-respiring goods (goods other than fruit and vegetables) where the goods are usually packed using the block stowage method and the air is only able to flow around the goods and not between the boxes. If the air is not able to transfer the refrigeration capacity to the cargo, this means that because the air is cooled rapidly because of the high capacity of the refrigeration unit but the cargo itself takes far longer to cool (see above).

The often repeated claim that goods in a refrigerated container cannot be cooled and that it is only possible to maintain the temperature in the container, is not valid as the information given above has shown. When transporting fruits, in particular bananas, the cargo is often cooled in the container. However, it is true that refrigerated containers are not suitable for providing high-quality freezing of products. It is possible to freeze products in a refrigerated container, but this process is relatively slow and leads to increased production of ice crystals which are simply not acceptable in a top-quality frozen product. For this reason, top-quality freezing results can only be achieved using specially designed equipment that freezes products very quickly.

8.4.4 Summary

In order to evaluate the temperature records made during refrigerated transport, it is absolutely necessary to be able to differentiate between the various temperatures that occur/may occur inside a container. This begins with the difference between the supply air and return air temperatures, which has a physical cause, and, in particular, includes the influences of stowage methods on local temperatures. On the other hand, it one must always take into account the possible temperature increases and distributions in order to interpret the plausibility of the temperature records.

Although it was not taken into account here, knowledge of the behavior of the various different refrigerated container models is nevertheless also important. To summarize:

No temperature record can be interpreted with absolute clarity; it is always necessary to interpret the data in the context of the circumstances, in order to be able to make reliable statements about the state of the cargo.

9 Controlled atmosphere in refrigerated containers

9.1 Biological principles

The use of CA extends the storage life of fruit and vegetables not only through cooling, but also by changing the air composition in the space (container) in which the goods are located. This generally involves reducing the oxygen content to 1 - 3% (normal air: 21%) and increasing the carbon dioxide content to 5 - 25% (normal air: 0.03%). The composition of the atmosphere that produces the longest possible storage life primarily depends on the type of fruit, the variety, its origin and the time of harvest.

Glucose (sugar):

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O \qquad RQ = 1.0$$

Organic acids:

$$C_4H_6O_5 + 3\,O_2 \longrightarrow 4\,CO_2 + 3\,H_2O \qquad RQ = 1.3$$

Long-chain fatty acids:

$$C_{18}H_{36}O_2 + 26\,O_2 \longrightarrow 18\,CO_2 + 18\,H_2O \qquad RQ = 0.7$$

Table 15: Various respiration types in fruits (glycolysis always predominates)

The correct atmosphere will slow respiration in the fruit (see table 15), thus ensuring longer storage life. Fruit respiration can be reduced by around 30 - 60% in comparison with normal atmospheric conditions with CA. This, of course, means that transport times can be extended, so that fruit, for instance, that is normally transported by air can also be transported by sea in refrigerated containers. Another possibility is to harvest the fruit later and hence achieve better quality fruit.

Figure 51 shows the effect of temperature on respiration for a number of different types of fruits and vegetables. The effects of changing the atmosphere must then be added to this.

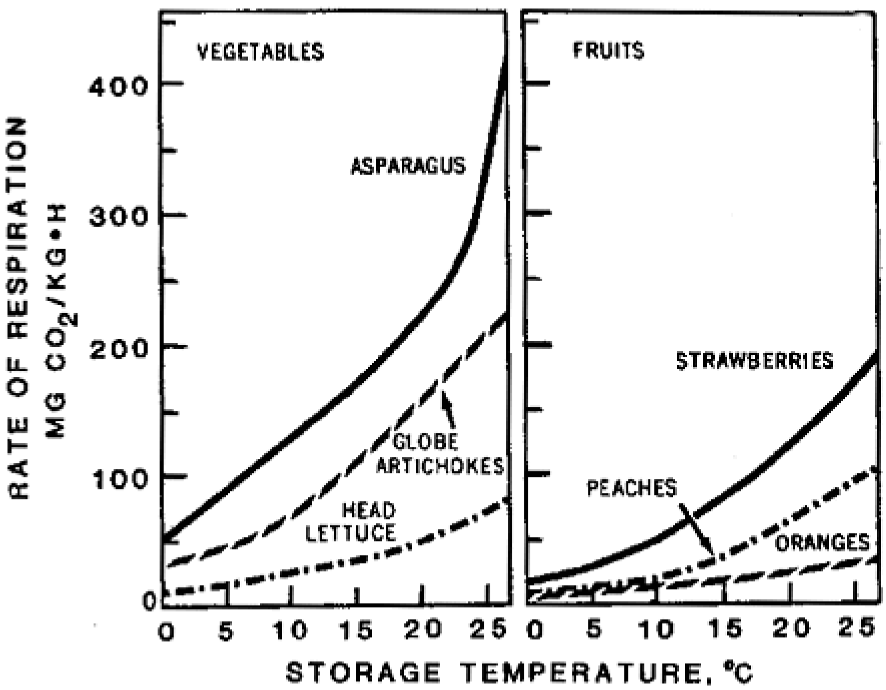
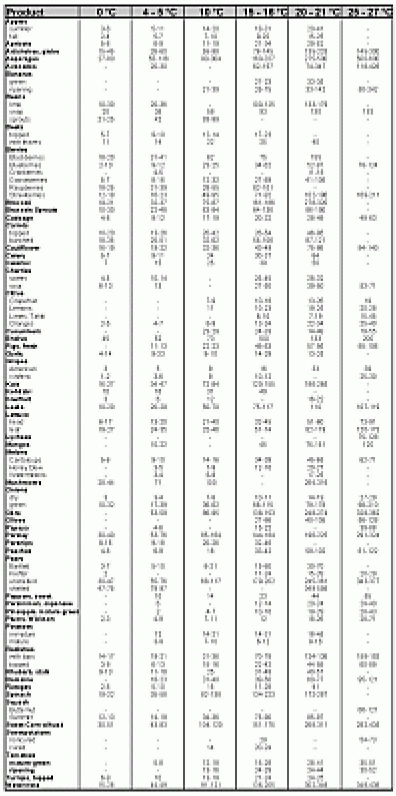
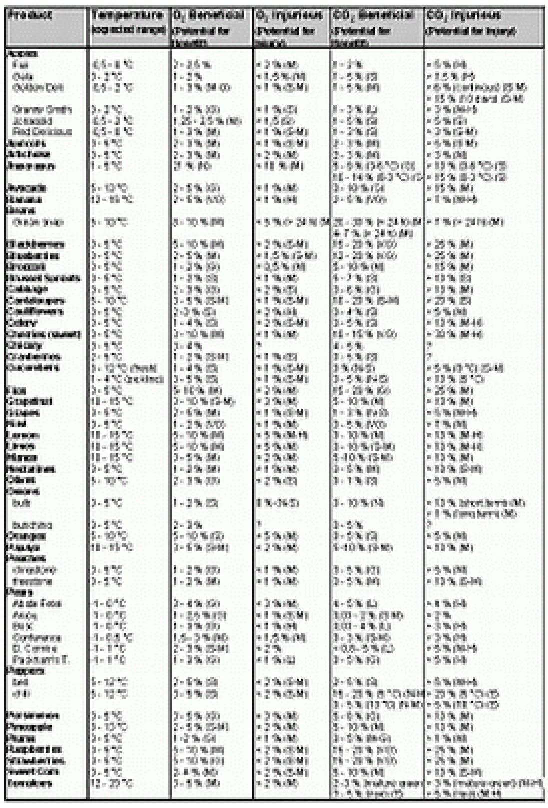


Figure 51: The effects of temperature on respiration



Click on the table to enlarge.

Table 16: Respiration of fruit and vegetables



Click on the table to enlarge.

Table 17: Recommended CA conditions for fruit and vegetables

Table 16 shows the respiratory activity of a large number of types of fruit and vegetables at various temperatures and normal atmospheric conditions. These can be used as guideline values when designing CA containers. Incorrect atmospheric composition can, however, also damage the products. If the oxygen content is too low or the carbon dioxide content too high, the fruit can be permanently damaged. In addition, it is necessary to ensure that ethylene, which is generated by fruit and accelerates ripening, is removed from the atmosphere.

Table 17 shows typical CA conditions for various fruit and vegetables. The critical values at which the oxygen content is too low and the carbon dioxide content is too high are also given.

9.2 Technical principles

9.2.1 Principle of nitrogen generation

9.2.1.1 Membrane type nitrogen separators

9.2.1.2 PSA type nitrogen generators

The availability of nitrogen is plays a crucial role in the use of CA, since the addition of this gas allows the oxygen and CO_2 content in a closed space to be reduced. There are two different procedures for separating nitrogen from the air: Membrane separation and pressure swing absorption (PSA).

9.2.1.1 Membrane type nitrogen separators

Gas separation membranes for separating nitrogen from air have been available since the mid eighties. The first membranes were spiral wound, but today, hollow fiber membranes are used. This allows the greatest possible surface area for gas separation in the smallest space.

The membrane itself consists of a polymer that is permeable to different degrees for different gases. In principle, almost all gases can pass through the membrane, but at different permeation rates. For the gases involved in CA applications, the following applies: Water vapor permeates fastest, followed by CO_2, O_2 and finally N_2. The ratio between the permeation rates of two gases is known as selectivity. The driving force for the exchange of gases is the partial pressure difference of the gases on either side of the membrane.

This effect is exploited in nitrogen separation, in that oxygen can be extracted from compressed air.

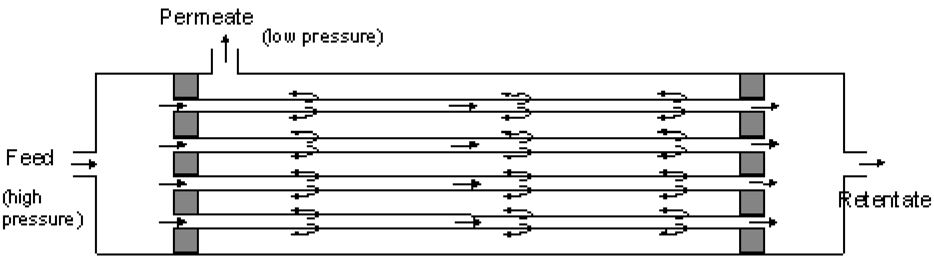


Figure 52: Fundamental structure of a gas separation membrane

Furthermore, higher membrane temperatures increase the degree of permeability, so that today, membranes are generally used at as high a temperature as possible in order to achieve the greatest possible yield from a small membrane. At the same time, the selectivity between oxygen and nitrogen drops as the temperature increases, i.e. the efficiency is reduced in relation to the volume of compressed air used. This effect is not significant with membranes which have a high selectivity to start with. If, however, the selectivity of a membrane is limited, it does not make sense to operate it at high temperatures.

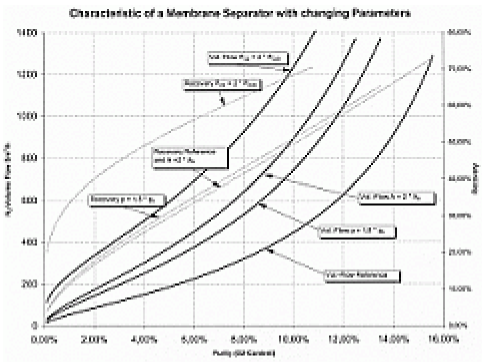


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Figure 53: Characteristics of a nitrogen separation membrane

Figure 53 shows the characteristic curves of a gas separation membrane. It shows the purity of the nitrogen produced and the yield (volume of nitrogen generated in relation to the volume of compressed air used) for a control membrane at constant pressure. The conditions were altered on the basis of this curve: The gas exchange surface was doubled (this corresponds to the use of two parallel membranes), the air pressure was increased by a factor of 1, and the permeability of oxygen was doubled (different membrane material).

Today, membrane systems are generally used if residual oxygen content of 1% is adequate. Greater degrees of purity can be generated more cost-effectively with PSA systems. For CA in refrigerated containers, membrane systems are now used almost exclusively, because they are based on a simple principle and can be constructed to be light and compact. They consist of the following key components (see Figure 54):

- Air compressor with a suction filter
- Filter and water extractor in the compressed air supply
- Heating component to heat the compressed air
- Gas separation membrane
- Choke point to reduce pressure

These are complemented by a number of safety features such as pressure valves, etc.

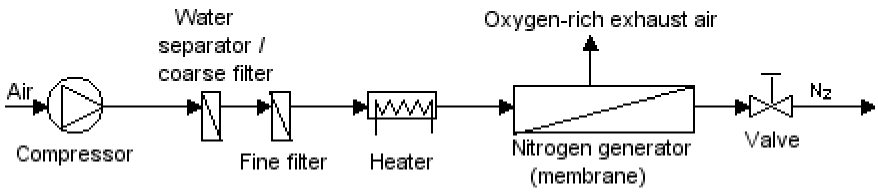


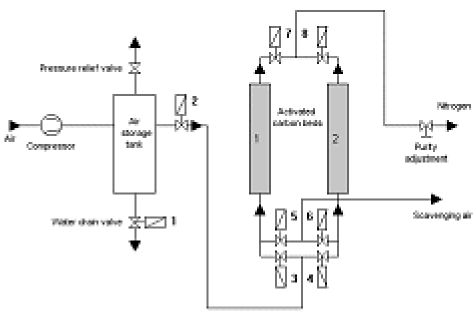
Figure 54: Basic principle of a membrane type nitrogen separator

9.2.1.2 PSA type nitrogen generators

The second way of producing nitrogen from air is the pressure swing absorption method (PSA). This takes advantage of a property of certain materials, namely that they bind (absorb) oxygen molecules under high pressure and release them again at low pressures. The process is not continuous, since the absorption material must be regenerated after every few minutes of operation. In order to achieve close to quasi-continuous nitrogen production, two or more absorption containers are interconnected, so that some containers absorb nitrogen while the others regenerate.

Figure 55 shows the principles behind this system. The switching sequence of the solenoid valves can be seen in Table 18. Due to the need for pressure containers to hold the absorption material, these systems are relatively large and heavy. The solenoid valves also represent potential sources of faults.

But from the point of view of efficiency (yield), PSA systems are favorable compared with membrane systems, particularly when high degrees of purity are required. It is not difficult for a PSA system to produce nitrogen with purity of 99.9% cost-effectively.



Click on the graphic to enlarge.

Figure 55: Principle of a PSA nitrogen generation system

Operating status	Solenoid valves							
	1	2	3	4	5	6	7	8
Bed 1 in operation / bed 2 regenerating	closed	open	open	closed	closed	open	open	closed
Pressure equalization	closed	closed	open	open	closed	closed	closed	closed
Bed 2 in operation / bed 1 regenerating	closed	open	closed	open	open	closed	closed	open
Water drainage	open	-	-	-	-	-	-	-
System shut-down	closed	closed	-	-	-	-	-	-

Table 18: Controlling a PSA system

A total of around 550 containers had been fitted with PSA systems by 2000. Such systems are not currently available on the market, since all the providers have either ceased production of this type of CA system or no longer exist.

9.2.2 The system in the CA space

The system in the CA space is largely determined by the following factors:

- Gas volume in the space. The general rule of thumb can be followed here that one third of the overall volume will be occupied by the cargo, and two thirds remain as the gas volume.
- The gastightness of the space (volume of ambient air which penetrates the space). This varies according to current operating mode (nitrogen addition on/off, speed of the fan, CO_2 scrubber on/off, etc.)
- The mass of the cargo in the space.
- The respiration activity of the cargo in the space. The general rule of thumb can be followed here that respiration activity of the cargo will be roughly halved under CA in comparison to respiration activity in the air. But of course the characteristics of the various different products also play a significant role here.
- Volume and purity of the nitrogen added.
- The behavior of other components (e.g. CO_2 scrubbers)

The interplay between these factors can be simulated easily, the least reliable factors being the gastightness of the container and the respiration activity of the products.

System data			Derived values	
Volume of hold [m^3] 40	**Suction leakage** [%*V/h] 1.00 %	**Respiration** [mg/kg h] 10	**Suction leakage** [m^3/s] 1.11E-04 [m^3/h] 0.4	**Cargo mass** [kg] 20,000.00
Quantity of N_2 [m^3/h] 6.30 [m^3/s] 0.002	**Purity of N_2** [%] 98.00 % N_2 2.00 % O_2			**O_2 consumption** [m^3/s] 3.28E-05

Theoretically calculated gas concentrations	
Achievable O_2- content [%] 1.36 %	**Achievable CO_2- content** [%] 1.77 %

	Nominal Value	Minimum	Maximum
Nominal value, O_2, separator	2.0 %	2.0 %	2.2 %
Nominal value, O_2, fresh air		1.8 %	2.0 %
Nominal value, CO_2	2.0 %	1.8 %	2.2 %

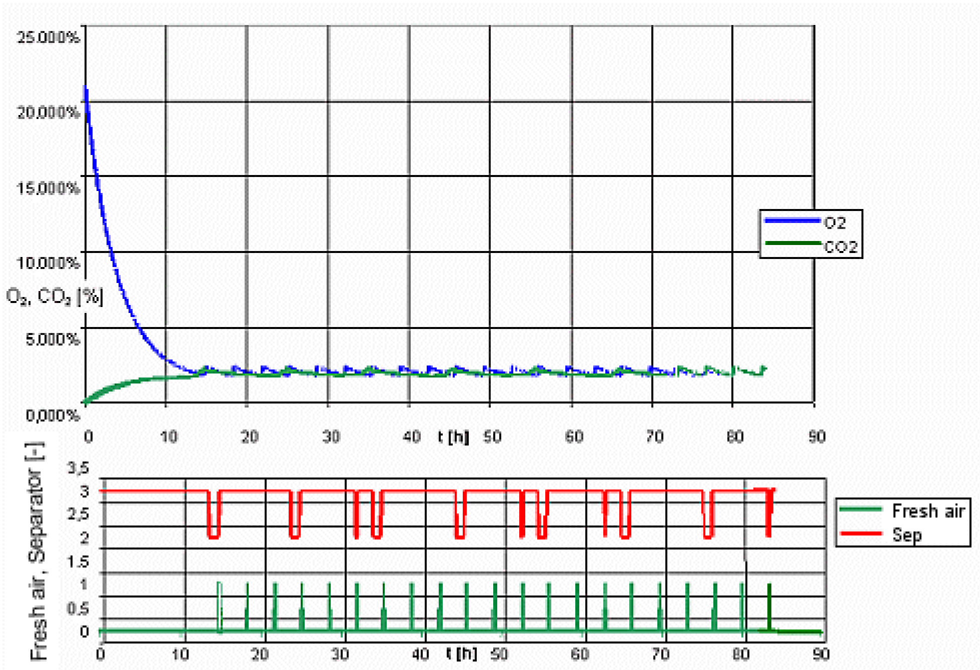


Figure 56: Simulation of the establishment of an atmosphere when using a nitrogen generator

9.2.3 Influence of the gastightness of the container

The gastightness of a container is crucial to a successful use of CA. The oxygen content can still be reduced in leaky containers if enough nitrogen is added, but the energy available for nitrogen production is limited (15 kW for the refrigeration unit and the nitrogen production together). It is also impossible to work with increased CO_2 content in leaky containers, since the large volumes of nitrogen involved drive the carbon dioxide produced by the goods out of the container. Thus, it is essential that the containers are sufficiently airtight before they are used in CA transportation.

9.3 CA in containers

After an introductory phase spanning several years, a stable trend can now be observed in the use of controlled atmosphere (CA) in maritime transport. The use of CA is particularly widespread in the transportation of mass refrigerated products, which are usually still transported on refrigerated cargo ships. This is particularly true of banana transportation, which comprises around 30% of refrigerated transport by sea, and of which around 60 - 80% is currently carried out under CA conditions in the holds of refrigerated cargo ships. Thus, the large banana companies are all employing this technology nowadays. Entire refrigerated cargo ship loads of apples and stone fruits are also transported under CA conditions.

The main reasons for the success of CA for relatively cheap mass products such as bananas are increased plantation production (the fruit can stay longer on the stalk, thus increasing in weight), reduced waste (on a refrigerated cargo ship with a load weighing 8,000 metric tons, a single percent waste equates to 80,000 kg) and higher product quality. The fact that marketing of these products from cultivation, through transportation right up to point of sale are in the hands of a single company, means that the benefits arising from CA, that despite everything are only in the region of a few percent, can actually be realized. If this were not the case, however, savings of this magnitude would soon be eaten up by the margins in the chain.

It is estimated that around 20 - 30% of cargo transported in refrigerated cargo ships is now transported under CA conditions. This technology is, therefore, already established in this area.

For containers, the situation has until now been different because a different kind of technology has been employed. As a proportion of the overall number of refrigerated containers transported (approx. 1.2 million per year), the number of transportations under CA conditions (around 48,000 to 54,000) represent only around 4 - 4.5% (figures for 2000).

Figure 57:
Container with a curtain in the doorway to increase gastightness

The large majority of these are also carried out by fruit companies, which transport their bananas in containers in particular to North America, but which also transport containers on the decks of refrigerated cargo ships. They generally use centralized systems for supplying nitrogen to the containers. Often, these systems are already in place on refrigerated cargo ships to supply the hold with nitrogen, but on dedicated container ships, special systems must be installed. It is estimated that around 38,000 to 42,000 FEU CA cargos are shipped every year with central CA systems such as this.

Active CA containers so far represent the smallest share of CA transport operations in containers. These containers have an in-built nitrogen separator and can establish the correct atmosphere autonomously. Around 1,800 to 2,000 of these containers are in use across the globe, and they make an estimated 4,000 - 5,000 CA journeys a year.

The passive CA system is relatively widespread. This demands that the containers are filled with the initial atmosphere at the port of loading.

This atmosphere is then sustained during transportation by the targeted addition of fresh air and removal of CO2. The main advantage of this system is that the necessary costs of modifying the containers are very low. Thus, around 45,000 containers globally have been modified for this system (all figures for 1999). This corresponds to around 10% of all refrigerated containers. Around 8,000 to 9,000 CA shipments are carried out annually with this system, primarily avocados, stone fruits, asparagus and broccoli. Almost all new refrigeration units are suitable for this system.

9.4 Economic aspects of CA transportation

Two points of view need to be taken into account when examining the economic feasibility of using CA: On the one hand, the point of view of the consignor, i.e. the owner of the load and on the other hand, that of the container owner, generally the shipping company or leasing company. It can, of course occur that these interests coincide, as in the case of the large fruit companies, for instance, who possess their own container stocks.

For the normal consignor, who purchases transportation services from a shipping company, the question is whether the higher costs for CA transport are justified. These increased costs are currently around $ 1,500.

If the load comprises a product that cannot be transported in the same quantities in normal refrigerated containers, but for which sea transportation under CA is a realistic possibility, the situation is as follows: At an estimated air freight price of $ 1 per kg, for instance, transportation of a load weighing 20 metric tons costs $ 20,000. Transport costs for a normal sea container are currently approx. $ 3,000 through $ 4,000, depending on the transport route. For CA, a further $ 1,500 must be added, thus giving overall transport costs of around $ 4,500 through $ 5,500. The cost benefits are obvious.

If the goods could be transported in a normal refrigerated container, but where a certain level of waste and loss of quality are inevitable, CA could be used in an effort to reduce the levels of waste or to improve quality.

If one assumes that most fruit and vegetables are relatively cheap products (compared with meat or fish) with purchase price of around $ 0.50 per kg, the waste quota must be reduced by around 3 metric tons for a 20 metric ton load in order to offset the cost of CA. Waste quotas of this kind (15%) are, however, unusually high for refrigerated transport and are only observed with a limited number of products. These include avocados, mangos, stone fruit and asparagus. These products already represent the highest proportion of goods transported under CA conditions.

If the primary benefit of using CA is the improvement in quality, the increased revenue generated by higher quality goods must be around $ 0.07 per kg for a load weighing 20 metric tons. Whether this increased revenue can be realized, however, also depends on other market issues.

The question of recouping costs is slightly different from the point of view of shipping companies. They must weigh up investment and operating costs against the increased revenue which can be generated from CA transportation.

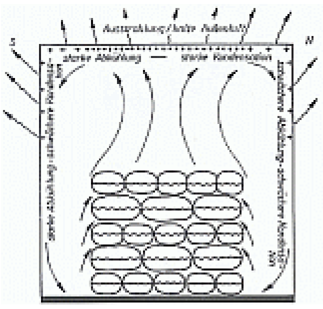
The key issue here is on how many CA transport operations can be carried out annually with such containers. As has already been described in Section 7.2, containers transporting bananas to North America can complete around 12 - 15

refrigerated voyages a year, the average for all refrigerated containers, however, is only around 2.9 voyages a year, and for shipping companies who use only containers, only around 2 voyages. These figures take account of all types of refrigerated goods, thus they include in particular frozen products, which comprise around 50% of the market for normal container shipping companies, and for which CA transport provides no benefit. If one also takes into account that by no means all fruit and vegetable shipments will be carried out under CA, but rather only around 50% of them, it becomes clear that, statistically, the possibility of using such a container for CA shipment will only occur once every two years. This means that in a case like this, depending on the manufacturer of the CA unit, between four and ten years will be required to recoup the original investment, and this calculation does not take account of the cost of borrowing or maintenance costs. If one also assumes that the operational life of this kind of CA container is between 5 and 8 years (not to mention the possibility that the CA unit is still operational, but the leakage of the container is unacceptable), it becomes clear that for the average container, the installation of a CA system is no longer economically viable.

The ideal customers for CA containers, are therefore owners that regularly and exclusively transport CA products. These are primarily the large fruit companies. Due to the fact that centralized CA systems are used on refrigerated cargo ships, however, these companies also use these centralized systems extensively for transporting containers.

Dr. Renate Scharnow

The product in the container



Preface

GDV's Loss Prevention Committee suggested that a container handbook be written in order to avoid transport losses and clarify their causation.

The transport properties of the products and their packaging form the theoretical foundation of this handbook. These properties are based on the water content, biotic activity and storage climate requirements of the goods. Using this method, it is possible to evaluate the suitability of the goods for container transport while taking account of risk factors applying, for example, to highly perishable goods, hygroscopic goods, liquid goods, industrial raw materials, semi-manufactured articles and industrial goods. The climatic conditions prevailing outside and inside the container are a major factor in evaluating the suitability of the goods for container transport, while examples of incidents of loss and hints for preventing such incidents are also given. Care has also been taken to ensure close links with the TIS Cargo information pages.

The author would like to take this opportunity to thank Captain Uwe Schieder for his commitment to the success of the Container Handbook, which he has followed from its inception and to which he has made many valuable contributions from his long practical experience. A group of experts, the Container Handbook working party, provided valuable support in the form of advice and appropriate illustrative material, so in particular ensuring the practical relevance of the Container Handbook.

Section 10, Climatic Conditions, made use of a paper given by Prof. Dr. Ulrich Scharnow on the occasion of the Loss Prevention Conference, 1998.

Captain Schieder is due thanks for his contribution of section 13.9, risk factor Mechanical influences.

The author would like to express her thanks to all those who have assisted her, including any who are not mentioned by name, and it is her hope that the Container Handbook will help to bring about a reduction in the constant losses arising from container transport.

10 Climatic conditions

10.1 Inclusion of hygroscopic goods in container transport

As the containerization of general cargo transport gained momentum, it extended to ever more types of cargo, including those requiring high levels of care on a conventional general cargo ship, so raising new issues with regard to the extent and effectiveness of measures to maintain the quality of the goods being carried.

The first phase of containerization primarily related to industrial products, machinery, preserved foods, chemical products etc., to which no particularly stringent cargo care requirements, other than cargo securing, applied even when conventionally carried. Container services thus developed rapidly between highly developed regions, such as Europe, North America and the Far East, whose products were particularly suitable for containerization.

The second phase of containerization then extended to include products for which standard containers did not provide ideal conditions, so resulting in further rationalization by the development of special containers, such as the bulk container, refrigerated container and tank container, some of which were devoted to a single product.

During this phase, however, efforts were also made to include products requiring cargo care, e.g. active ventilation, during maritime transport on conventional general cargo ships. The next target was to include the large group of hygroscopic goods, i.e. goods exhibiting an interaction between water content and relative humidity.

This third phase of containerization was necessary in order to allow the carriage of sufficient quantities of containerized goods in both directions on certain routes and to increase the overall volume of containerized transport. High levels of containerization made it necessary to develop methods which enable the widest possible range of products to be carried using containers.

When the container transport system was being designed and rolled out, the initial assumption was that using containers would substantially simplify or completely solve many problems relating to caring for, packaging and maintaining the quality of cargoes during maritime transport. It was soon obvious, however, that simply putting the goods inside the container was not enough, that in addition to simplifying matters new problems arose in terms of maintaining quality, e.g. avoiding corrosion of metal parts and that packaging, instead of becoming superfluous, had to provide new protective functions.

These issues can be addressed in three ways:

1. the development of special containers in order to adapt them to the requirements of the goods
2. increasing the "fitness for container transport" of the goods by additional treatment (e.g. drying, preservation) or by suitable packaging
3. providing appropriate cargo care for containers carrying critical products by selecting a suitable type of container and stowage space, stuffing the cargo properly and using the ship's ventilation system. For example, coffee has been transported in ro/ro ships from West Africa on flatracks ventilated with the ship's ventilation system.

All three approaches are based on the physical, chemical and biological properties of the product, make use of established product information and attempt to create suitable transport conditions for the product.

The primary aim in developing new structural solutions, such as bulk containers, open-top containers, open-sided container or flatracks, was to minimize transport costs, e.g. loading and unloading costs and the use of container services.

These new container types do, however, result in modified storage and stowage conditions, as the climatic conditions to which a product is exposed in a closed standard container are completely different from those on a flatrack.

In order to extend the range of goods which can be transported in containers, special containers were developed with the emphasis on maintaining cargo quality, e.g. the thermally insulated container which has thermal insulation to provide protection from major temperature fluctuations and, by connection to a refrigeration unit, can become a refrigerated container. Passively and actively ventilated containers were developed to allow the air exchange required for carrying certain sensitive groups of products.

The costs of using specialized containers are high, so their use is only justified if they are filled with products which make use of these particular advantages of the special container. There are relatively tight limits on how far a container can be adapted to a particular product, in that each adaptation to one group of products generally excludes or at least restricts the carriage of other groups of products. For example, while the open container can indeed be more easily loaded with heavy cargo (machinery) than can the closed container, the open container cannot be loaded on the return voyage with goods, such as those packaged in bags and cartons, which require protection from environmental conditions. Products which are more advantageously transported in special containers are, however, not always available in identical quantities in both directions. Carrying empty containers further increases the cost of transport in special containers. It is consequently not possible to keep on developing new kinds of special containers as each kind requires a certain volume of its specialty cargo.

This explains the great importance of modifying certain cargo properties in order to make the cargo suitable for carriage in a standard container or "fit for container transport". "Fitness for container transport" generally assumes carriage in a closed standard container.

From the standpoint of the product, transport in a container amounts to storage in a more or less closed space with exposure to the cryptoclimate prevailing in this space. A product which is "fit for container transport" must be able to withstand this cryptoclimate without being impaired in quality. If it is possible to adjust the state of the product such that transport in a standard container is possible, then this is an economically sensible solution for the transport of this product.

10.2 Fundamental issues relating to container climate

10.2.1 Temperature & water vapor content of the air

Mollier h/x diagram

Some fundamental product information issues need to be brought to mind for the following explanations.

Air always contains a certain proportion of water vapor, approx. 3 g/m³ in cold, dry air, as much as 30 g/m³ in warm, humid air. This is only a small proportion, amounting to at most 3% of the mass of the air, but has a considerable meteorological impact, as is clear from the day to day changes in the weather.

Decisively, the atmosphere can only contain a certain quantity of water vapor, the saturation content, which is dependent upon temperature. The hotter is the air, the more water vapor it may contain.

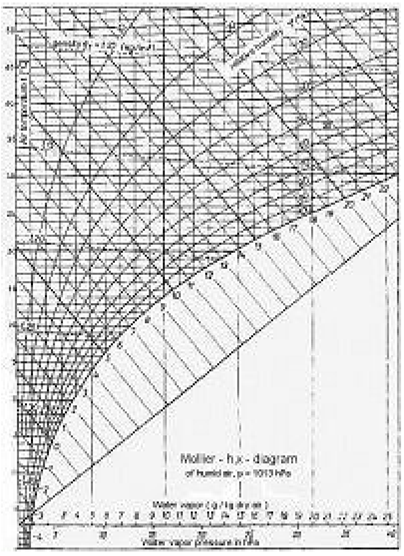


Figure 1: Mollier h/x diagram

(Click on graphic to enlarge)

Once the saturation content is reached, no further water can evaporate. Relative humidity is now 100%. A relative humidity of 60% means that air contains 60% of the saturation content.

The lower the rel. humidity, the more intensively does water vapor adsorption proceed, so bringing about a drying action.

One clear parameter which indicates the risk of sweat formation is the dew point temperature of the air. This is the temperature at which the water vapor contained in the air reaches its saturation content and, if cooling continues, condensation occurs.

If the dew point temperature is known, it is possible to estimate the risk of sweat. The interrelationships between these variables are presented in diagrams. Fig. 1 shows a Mollier h/x diagram which is very well suited to such conversions.

The temperature values, i.e. air and dew point temperature, can be read from the Y-axis, while the mixture ratio x (g/kg) can be read from the X-axis. The mixture ratio x states how much water vapor one kilogram of dry air contains.

The curves running from the bottom left to the top right indicate the relative humidity in 10% increments. The bottom curve applies to a humidity of 100% and is thus known as the saturation curve. The position of a given mass of air within these coordinates must always be defined by at least two values, one of which should always be the air temperature. The second coordinate is then determined by the mixture ratio x, relative humidity or by the dew point.

Fig. 2 shows examples of the use of a Mollier h/x diagram.

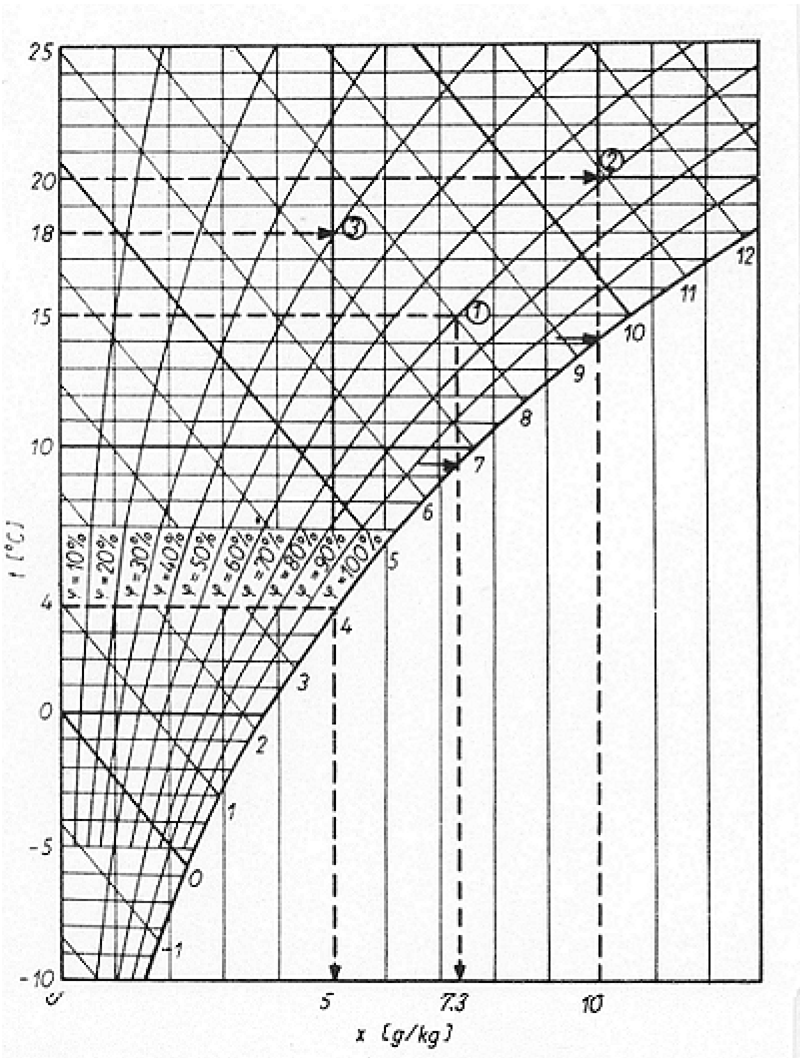


Figure 2: Examples of the use of a Mollier h/x diagram [46]

The following three examples show how, starting from the known values, the others are determined. All the points from which the results are read off are indicated with an arrow in the Figure.

Example 1:
The air temperature t = 15°C and
relative humidity φ = 70% are known;
Root: the mixture ratio x and dew point τ.
Result: x = 7.3 g/kg τ= 9.5°C

Example 2:
The air temperature t = 20°C and
mixture ratio x = 10 g/kg are known;

Root: relative humidity φ and dew point 𝔗.
Result: φ = 69% 𝔗= 14.1°C

Example 3:
The air temperature t = 18°C and
dew point 𝔗= 4°C are known;
Root: relative humidity φ and mixture ratio x.
Result: φ = 39% x = 5.0 g/kg

10.2.2 Hygroscopicity

Hygroscopic goods place particularly severe demands upon container transport. Hygroscopicity is the term used to describe the capability of goods to respond to the moisture content of air by absorbing water vapor from the air or releasing water vapor back into the air. Of decisive significance for the absorption or release of water vapor are:

- the relative humidity of the ambient air
- the water content of the goods (product moisture content)
- temperature.

Many hygroscopic goods are of organic origin. However, many chemical products, even those of inorganic origin, are hygroscopic and require that appropriate attention be paid to this property during container transport.

These goods are often also the root cause of damage to hygroscopically neutral goods, such as metals and metal products, by providing a source of elevated relative humidity in the container or of sweat and so causing corrosion.

10.2.3 Water content of the goods

The water content of a product is the percentage of its total mass which is constituted by water.

Hygroscopic goods have the characteristic of a variable water content. They are capable of absorbing water vapor from the air or releasing it back again. In a first approximation, it may be stated that:

In ambient air of low relative humidity, they release water vapor, while in ambient air of high relative humidity, they absorb water vapor. They are thus capable of modifying the proportion of their mass constituted by water, i.e. the water content of the product.

A product is referred to as "container dry" when its water content is such that, under normal weather conditions during packing and transport of the container, it results in no impairment of quality. In the case of organic products, an excessively high water content may result in mold, rot and biochemical changes, such as with cocoa and coffee beans. For some products, these phenomena are also associated with self-heating, which may go as far as spontaneous combustion, for example oil-bearing seeds and feedstuffs containing residual oil.

Critical water content means a water content which, if exceeded during container transport or storage, must be expected to cause the onset of the listed disadvantageous changes.
For safe transport, it is therefore important for the water content of a product to match the required values on acceptance in the container and for this water content to be maintained in transit, which must be ensured by the storage conditions.

10.2.4 Sorption behavior

Sorption behavior is the term used to describe the characteristic of hygroscopic goods, as a function of temperature and of a particular water content of the product, to absorb or release water vapor from or into the ambient air until a state of equilibrium is established.

Sorption behavior is determined by a partial pressure gradient, in which in accordance with the diffusion law water vapor always flows from the higher to the lower partial pressure until a vapor pressure equilibrium is established. Intake of water vapor is here known as adsorption, while release of water vapor is known as desorption (see Fig. 3).

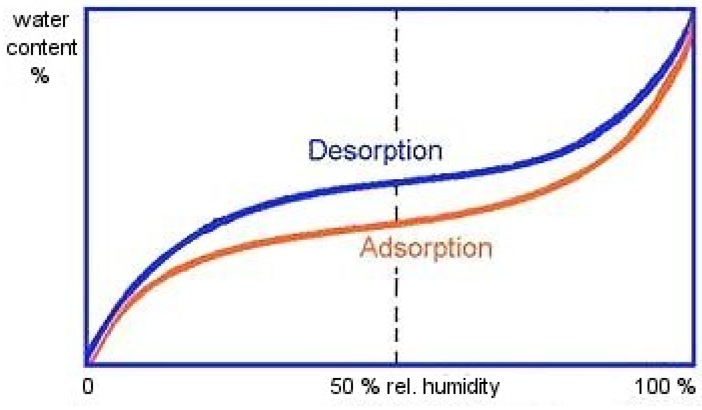


Figure 3:
Adsorption and desorption curve;
Tietke [58]

Y-axis: water content
X-axis: relative humidity

10.2.5 Sorption isotherms

A sorption isotherm is the graphic representation of the sorption behavior of a substance. It describes the relationship between the water content of the substance and the relative humidity of the ambient air at a particular temperature.

In a closed container, as a function of the water content of the substance, the relative humidity indicated by the sorption isotherm is established until an equilibrium between the product and ambient air is reached. This is known as the equilibrium moisture content. A graphical plot of the equilibrium states between the product partial pressure, which is dependent upon the water content, and the ambient air for a specific temperature produces the sorption isotherm, which consequently describes a product's sorption behavior. If a product's water content is known, it is possible to use the sorption isotherm to determine how the product will behave in the container or how the storage conditions or cryptoclimate will vary.

When determining the equilibrium states between the product and the ambient air, differences are found between the values which are measured during water vapor adsorption (adsorption isotherm) and those which are measured during water vapor release (desorption isotherm). The values for the desorption isotherm are always somewhat higher than those for the adsorption isotherm. The differences between adsorption and desorption isotherms are at their greatest at moderate relative humidities (Fig. 3). The adsorption isotherm at 20°C, which describes the state of hygroscopic goods after manufacture, is generally used in practice.

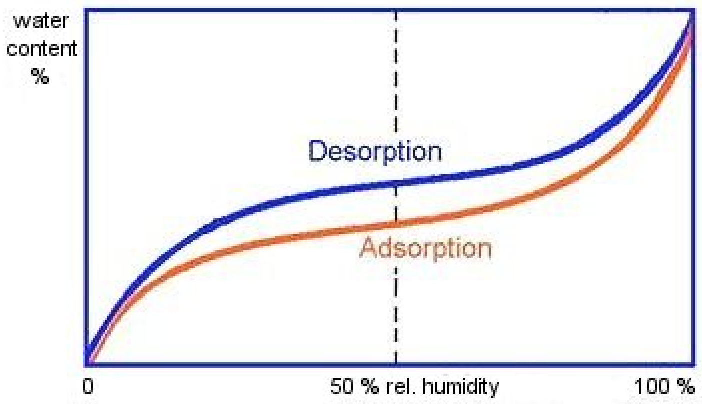


Figure 3: Adsorption and desorption curve;
Tietke [58]

Y-axis: water content
X-axis: relative humidity

The profile of a sorption isotherm is characteristic of the hygroscopicity of a product. Highly hygroscopic substances exhibit a steep sorption isotherm, while sparingly hygroscopic goods exhibit flat sorption isotherms. Weakly hygroscopic goods exhibit no or only a slight change in their water content as a consequence of variations in relative humidity.

10.2.6 Representation of the sorption behavior of a product using the temperature/dew point difference

Another way of representing the equilibrium relationships between a hygroscopic product and the water vapor content of the ambient air is to state the temperature/dew point difference, which is defined as the difference between the temperature of the air in immediate contact with the product (product temperature) and the air's dew point.

Fig. 4 is a representation of sorption isotherms by plotting the temperature/dew point difference of the ambient air

(Y-axis) against the water content of the product (X-axis), with indication of the critical water contents (X_k).

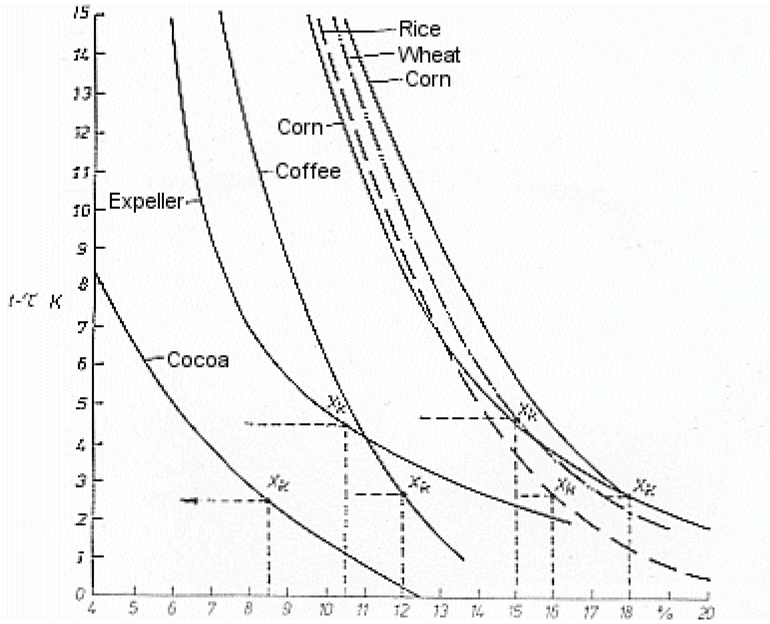


Figure 4: Temperature/dew point difference of the ambient air as a function of product water content
X_k: critical point
[27]

In the case of container dry green coffee beans with a water content of 10% and a temperature of 20°C, the equilibrium moisture content is 69% according to the sorption isotherm; according to the Mollier h/x diagram, the dew point is 14°C and the temperature/dew point difference is thus 6°C.

If the green coffee beans have a critical water content of 12%, an equilibrium moisture content of 86% is established at 20°C and the dew point is 17.2°C, giving a temperature/dew point difference of 2.8°C. It is clear from the above that, from the outset, this coffee is exposed to the risk of mold growth, mustiness and fermentation and sweating will occur much earlier than in the case of container dry coffee.

The following conclusions may be drawn:

- the temperature/dew point difference is dependent upon a product's water content
- the lower is the product's water content, the greater is the temperature/dew point difference; the product is container dry
- the greater is the product's water content, the smaller is the temperature/dew point difference and the greater is its tendency to sweat on cooling and thus undergo disadvantageous changes, such as mold growth, mustiness and fermentation, postfermentation and self-heating.

10.2.7 Types of sorption isotherm

In general, a distinction may be drawn between three types of sorption isotherms (Fig. 5):

1. Sorption isotherm rises steeply, i.e. the product is strongly hygroscopic, as is the case with silica gel (desiccant for corrosion protection) or dried fruits.
2. In contrast, sucrose or tartaric acid exhibit an abrupt change in the sorption isotherm profile. Over a wide range, until the equilibrium moisture content of approx. 85% is reached, water adsorption is low and the product exhibits scarcely any hygroscopicity (anhydrous form); once the flow moisture point has been reached, sucrose rapidly absorbs large amounts of water vapor, causing it to deliquesce, so explaining the steep rise in the second branch of the curve (formation of hydrate). This type of sorption isotherm is typical of many crystalline goods, such as for example salt, sugar, potash and other fertilizers.
3. The third type of sorption isotherm has an S-shaped profile, which most hygroscopic goods exhibit, such as for example wheat or long-life cakes and cookies.
   X_{K1}-X_{K3} in Fig. 5 denote several critical water contents for various technological properties, such as flavor retention, crispness and mold growth in long-life cakes and cookies. The water present around X_{K1} is strongly adsorbed and occurs at comparatively low relative humidities.

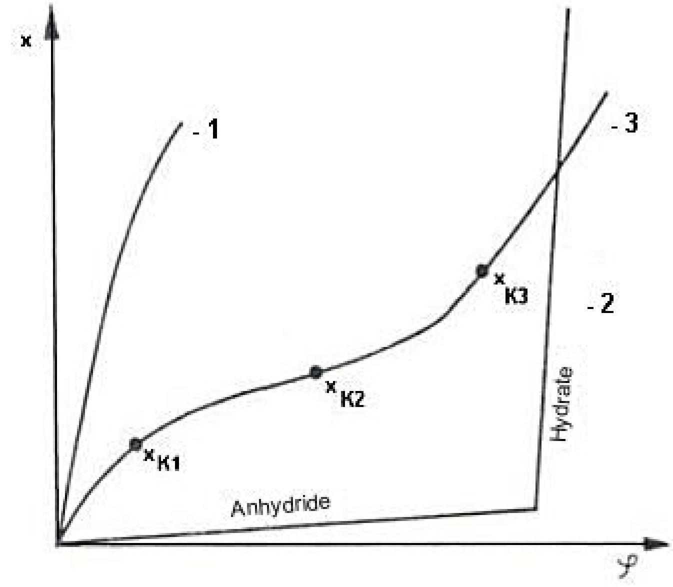


Figure 5: Types of sorption isotherms;
Heiss [16]

X_{K2} is the inflection point of the S-shaped sorption isotherm which, in the zone above X_{K3}, is frequently characterized by a more or less steep rise at higher relative humidities. The range between X_{K1} and X_{K3} in Fig. 5 is the range of greatest stability in technological properties; in the present case, this range is at water contents of 5.2 - 10.1% and no disadvantageous changes in the product are to be anticipated within these limits.

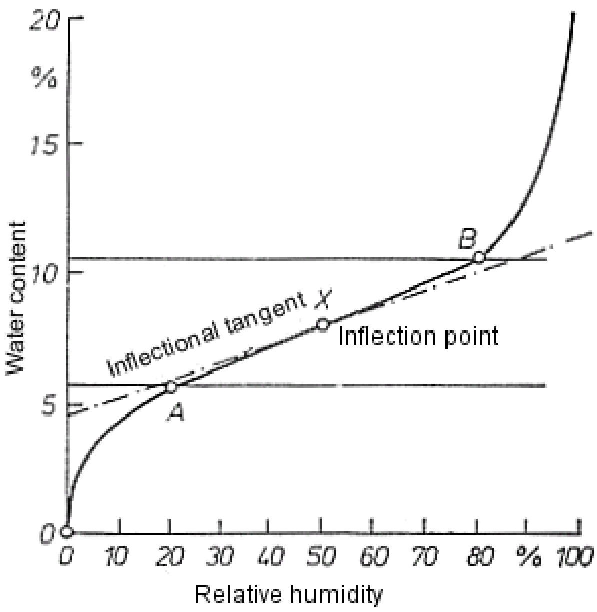


Figure 6: Sorption isotherm showing the range (A-B) of greatest stability in technological properties;
Acker [27]

In paper, for example, greatest strength is observed at water contents of between 5.1 and 7% (see Fig 7).

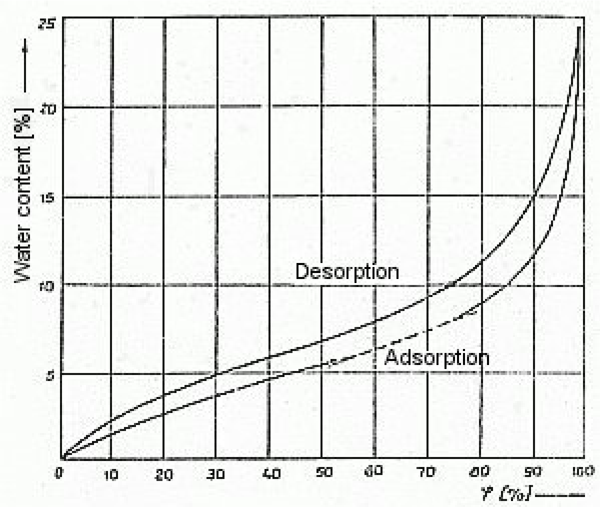


Figure 7: Sorption isotherms for paper (20°)
---- range of greatest stability of technological properties [45]

10.2.8 Water vapor in container air

The following sorption isotherms for wheat (Fig. 8) are intended to illustrate the types of question about the behavior of hygroscopic goods which can be answered using sorption isotherms. The sorption isotherm for 20°C indicates equilibrium states between the water content of the wheat and relative humidity.

1. Higher water contents of the wheat are associated with higher relative humidities than equilibrium moisture contents and vice versa.

   For example:

Water content of wheat	Relative humidity
12%	55%
13%	65%
15%	75%

2.
3. At a measured water content of 18% (point 1) and a relative humidity of the ambient air of 75%, the point of intersection lies above the sorption isotherm. In an unventilated bulk container, the relative humidity will increase until a state of equilibrium is reached at a relative humidity of approx. 88% (point 2). The mold growth threshold, which is at 75% relative humidity, is thus exceeded. The onset of mold formation may accordingly occur in the closed container. The product's water content does not change owing to the slight release of water vapor which is required for this to happen. This situation would have to be rectified by ventilation, the cargo theoretically being dried with suitable ventilation air until its water content was just below 15% and a state of equilibrium with the ambient air had therefore been reached.

   For example, if it were desired to adjust 100 metric tons of cereal with a water content of 16% to a water content of 13%, 3 metric tons of water vapor would have to be removed by ventilation; however, in practice, thorough drying of excessively moist cargo is not possible.

   The grain would spoil due to mold growth in parts of the container or within the cargo (dead air zones).

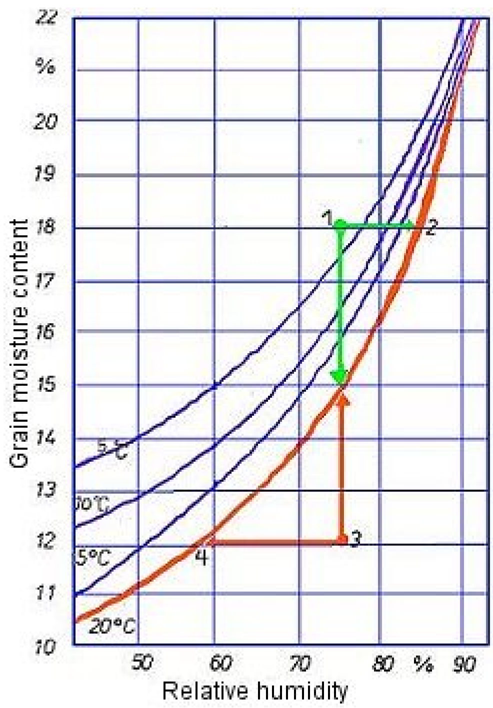


Figure 8: Sorption isotherms for wheat at various temperatures [27]

4.
5. The water content of the product is below the sorption isotherm: (Fig. 8). At a measured water content of 12% and a relative humidity of the ambient air of 75%, the point of intersection lies below the sorption isotherm (point 3).

   In an unventilated bulk container, relative humidity would decrease as a result of water vapor adsorption by the hygroscopic product until a state of equilibrium was reached at a relative humidity of just below 60% (point 4). Since the amount of water vapor to be adsorbed is small, the water content of the product hardly changes during this process. There is generally no risk of impairment of quality.

   If it were possible to ventilate the bulk container constantly with air of a humidity of 75%, the grain would gain water content until the equilibrium state was achieved at 15%. In this case too, no spoilage would occur as a cereal moisture content of 15% is still within the transportable range.

   Critical water content means a water content which, if exceeded during container transport or storage, must be expected to cause the onset of quality degradation, such as mold, fermentation, rot, self-heating/spontaneous combustion.

   Such damage occurs at relative humidities of > 75% in the container; relative humidities of 60 - < 75% are safe storage conditions for the majority of products.
   Container dry describes a product which has a water content such that it does not suffer any impairment of quality under normal weather or container conditions.

   For safe transport, it is therefore important for the water content of a product to match the required values when the container is packed and for this water content to be maintained in transit through the storage climate conditions in the container.

   The following factors must accordingly be taken into account in container transport:

   - check water content by measurement before packing the container
   - find out the intended route (climatic zones)
   - determine the season of transport?
   - does the water content correspond to the anticipated conditions?

   To summarize:

   In an unventilated container packed with a hygroscopic product, the product determines the relative humidity in the container, i.e. the product creates its own atmospheric environment. During these balancing processes, the product itself undergoes only slight changes to its water content, since this quantity of water is a multiple of the absolute humidity of the container air.

In a container which is ventilated or accessible to the air and is packed with a hygroscopic product, the relative humidity of the container air depends on the external air values, the product being able to absorb or release water vapor accordingly. It should be noted that only when a product is subjected to constant ventilation with excessively moist or dry air for several days or weeks does its water content increase or decrease slowly. It should also be noted that, even when a container is ventilated, the air between particles (e.g. cereal grains, coffee or cocoa beans) or in dead air zones behaves as if the container were closed, i.e. unventilated.

6. Influence of product temperature on equilibrium moisture content:

   If the temperature of the product changes, this change modifies the equilibrium humidity conditions. Since a 10°C sorption isotherm is, for example, higher than a 20°C sorption isotherm, identical water contents correspond to lower equilibrium moisture contents of the air. For example, the equilibrium moisture content for wheat with a water content of 15% and an intrinsic temperature of 20°C is approx. 75%; by contrast, at an intrinsic temperature of 10°C, the equilibrium moisture content is approx. 68%. Consequently, for example on a route to Canada or the USA, the admissible water content for cereals may be higher at the prevailing low air temperatures without the critical relative humidity of > 75% (mold growth threshold) being exceeded in transit.

   For goods of vegetable origin loaded in tropical ports, these equilibrium relationships mean that it is essential to take full advantage of every opportunity to cool the goods. Warm products, such as cocoa beans from Lagos or coffee beans from Santos, release large amounts of water vapor and lead more quickly to sweat formation.

10.2.9 Definition of moisture sensitivity

"Hygroscopicity" should not be confused with "moisture sensitivity".

A product is sensitive to moisture if even slight water vapor adsorption rapidly causes severe changes, especially if these changes occur at low relative humidities, such as the loss of crispness in rusks which occurs at a relative humidity of only 50%; see also point X_{K2} in Fig. 5 for long-life cakes and cookies.

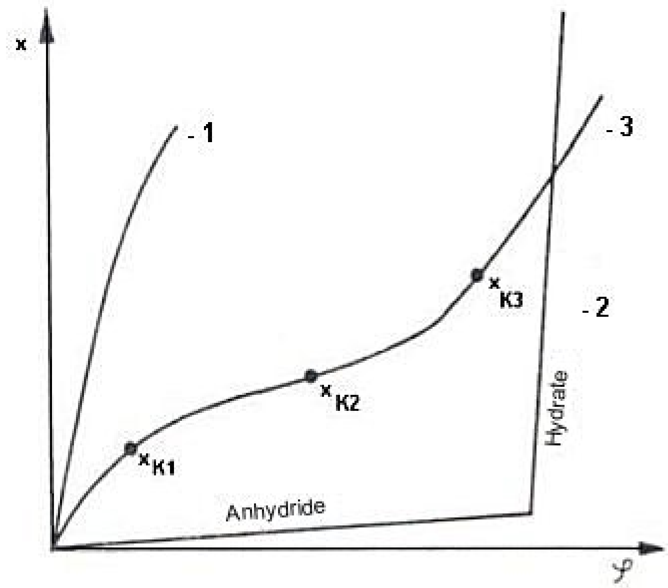


Figure 5: Types of sorption isotherms
Heiss [16]

Crystalline goods such as sugar, salt, fertilizer are slightly hygroscopic, but very sensitive to moisture at the point at which the flow moisture point is reached and the product deliquesces.

Coconut fat is absolutely not hygroscopic, but even slight traces of water cause the coconut fat to become soapy.

Ferrous and other metals are not hygroscopic, but they are extremely sensitive to moisture, with corrosion rapidly increasing from a relative humidity of < 50%.

10.3 Cryptoclimate in the container and climatic influencing factors

10.3.1 The significance of interfaces for the cryptoclimate in the container

An examination of published incidents of loss due to climatic factors involving container cargoes reveals that such incidents affect the entire range of products with no particular class of product being disproportionately represented. On the basis of the published examples, losses caused by sweating are clearly the most striking. Sweating includes both that which occurs on the cargo itself (cargo sweat) and that which drips down onto the cargo from the upper surfaces of the container (container sweat). All classes of goods are affected by this type of loss. For example, reported losses range from nonhygroscopic gods, such as steel and steel products, canned foods, to hygroscopic goods, such as cocoa, coffee, millet, dried fruit, sago, pepper, milk powder, furs, textiles and rattan furniture.

In addition to the preponderance of losses due to sweat, a second problem is particularly noticeable, namely the care which is required to adapt the goods, loaded under the climatic conditions of the place of departure, to the climatic conditions of the destination while in transit, without causing damage to the goods or making such damage inevitable due to inadequate adaptation. The theoretical basis on which these issues are addressed resides in "interfacial" physics, which take account of the differences in heat and water vapor transfer at interfaces. The most important basic requirement in this connection is to prevent condensation of the water vapor present in the air at an interface, whether on the container wall boundaries, on the surface of the cargo, in air layers in the vicinity of interfaces or within cargo blocks, if the temperature of the interface falls below the dew point temperature of the surrounding body of air. This requirement in turn makes it necessary to adapt the temperature of the cargo to the anticipated air temperature at the destination. Abrupt changes in temperature or humidity or both occur at these interfaces.

The following types of interface in container transport may be distinguished on the basis of their thermal and hygroscopic properties:

1. Container parts as 1st order interfaces

1. Container parts as 1st order interfaces
   These include interfaces which exhibit good heat transfer, are impermeable to water vapor and on which relatively large variations in temperature occur on exposure:

    - container walls and ceilings

2. Container parts as 2nd order interfaces
   These include interfaces which, in addition to exhibiting good heat transfer, are also permeable to water vapor or actively interact with the water vapor in the container:

    - wooden dunnage
    - dunnage

3. Cargo surfaces as 1st order interfaces
   Hygroscopic goods which release heat and water vapor into the container air. These include:

    - actively respiring goods of vegetable origin
    - goods of vegetable or animal origin or chemical products which, as a result of ongoing biological or chemical processes, have a tendency to undergo self-heating and are capable of exchanging water vapor with the air

4. Cargo surfaces as 2nd order interfaces
   nonhygroscopic goods with surfaces having good thermal conductivity and a relatively large heat capacity of the individual package or stack:

    - unpackaged metallic surfaces
    - hygroscopic and nonhygroscopic goods packaged in metallic containers or metal foils as the surface

5. Cargo surfaces as 3rd order interfaces
   Surfaces of hygroscopic goods capable of heat transfer and permeable to water vapor which exchange heat and water vapor with the container air without actively generating heat or requiring this exchange in order to retain service properties:

    - salt and fertilizer
    - sugar
    - hygroscopic minerals, ores and rock
    - lumber, furniture
    - general cargo packaged in wooden cases

10.3.2 Storage temperatures in the container

10.3.2.1 Influence of solar radiation

10.3.2.2 Depth of penetration of temperatures

If the correct decision as to the suitability of a container for transporting a product without causing damage is to be made, it is essential to have sufficient information about the anticipated climatic conditions in the container. Fig. 9 shows factors which have an influence on the cryptoclimate in the container.

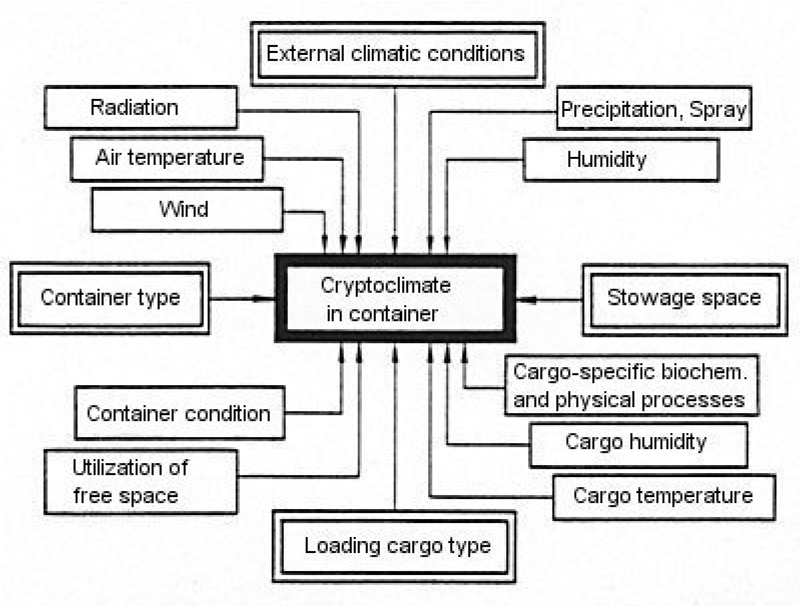


Figure 9: Factors influencing container cryptoclimate [42]

The four decisive influencing factors are:

- weather conditions during the voyage
- the type of cargo with which the container is packed
- the type of container
- the container stowage space

Clarifying the complex thermodynamic processes occurring in containers, especially in containers exposed to radiation, was the objective of the hold meteorology study group at the Warnemünde-Wustrow University of Seafaring (Fig. 10), where cryptoclimate was investigated in two containers, both on a test rig and on board commercial vessels. The investigations were carried out on two standard containers, each of which was equipped with an air lock to prevent disturbing the cryptoclimate when monitoring and making measurements and a weather station. The containers were packed with hygroscopic goods, in particular sawdust in one case and packets of sugar wrapped in paper in the other.

Climatic conditions during the voyage are determined by the route, season and current weather events. Consequently, it is not entirely straightforwardly possible to transfer the experience gained from one voyage or one route to another as the stresses vary between the different routes and individual voyages. Solar radiation, air temperature and wind are of significance to thermal stress.

The temperatures encountered in containers are primarily determined by heat exchange across the steel boundary surfaces, with inward and outward radiant transfers predominating.

Figure 10: Hold meteorology study group of Warnemünde-Wustrow University of Seafaring, 1970: container with air lock and weather station;
Svenson [54]

Good heat-transfer properties, especially through the metal walls, and the relatively large ratio of container surface area to container volume have a favorable impact in this respect (20' container, approx. 1.80 m^2/m^3).

10.3.2.1 Influence of solar radiation on daily variation in container temperature - radiation classes

The average air temperature in the container and also the temperature of the cargo surface are, on a daily average, higher than that of the external air.

The daily variation in the individual temperatures is of great significance to maintaining quality.

In addition to radiant conditions, external air temperatures, wind and precipitation also have an impact upon temperatures. The great daily variation in overall radiation results in a marked variation in temperature within the container. This variation primarily affects the temperatures of the container air and in particular of the bodies of air in those areas exposed to radiation (e.g. under the container ceiling).

Overheating of the air inside the container, i.e. heating to above the external air temperature, may be considerable even under normal conditions.

For example, daily overheating on sunny summer days amounts on average to 20°C even in temperate latitudes and is still higher in the subtropics. This means that temperatures of > 50°C, to which the surfaces of the cargo are exposed, may occur in the upper part of the container.

Four radiation classes were defined to describe radiation conditions, the classes being calculated on the basis of the measured duration of sunshine and solar altitude for 10 day measurement periods. The classes may be described in words as follows:

Class A:
Little or no effect of solar radiation. Average maximum overheating is 2.0°C (less than three hours of sunshine per day with low solar altitude, no radiant input on several days of the 10 day measurement period).

Class B:
Weak effect of solar radiation. Average maximum overheating is 5.2°C (four to eight hours of sunshine per day, but without sunshine on each individual day of the measurement decade).

Class C:
Moderate effect of solar radiation. Average maximum overheating is 11.5°C (up to twelve hours of sunshine per day, but without sunshine on each individual day of the measurement decade).

Class D:
Strong effect of solar radiation. Average maximum overheating is 17.3°C (more than twelve hours of sunshine per day, in general on all days).

Class A primarily occurs in Central Europe during the autumn and winter months, class B in the autumn and spring, class C in the summer and class D in periods of radiation weather in high summer which are similar to

subtropical conditions.

Fig. 11 shows air overheating at an upper measurement point in a stationary container. The values were plotted by radiation class. It should be noted that the overheating values shown in Fig. 11 are averages. Overheating of 20 - 25°C was measured at an upper measurement point in the container in

0.0% of class A,
0.8% of class B,
5.4% of class C,
25.5% of class D,

as a proportion of all measurements, with overheating in class D being in the
15 - 25°C range in 83.6% of all cases. At an external air temperature of 25 - 30°C, air temperatures within the container may accordingly rise as high as 50 - 55°C.

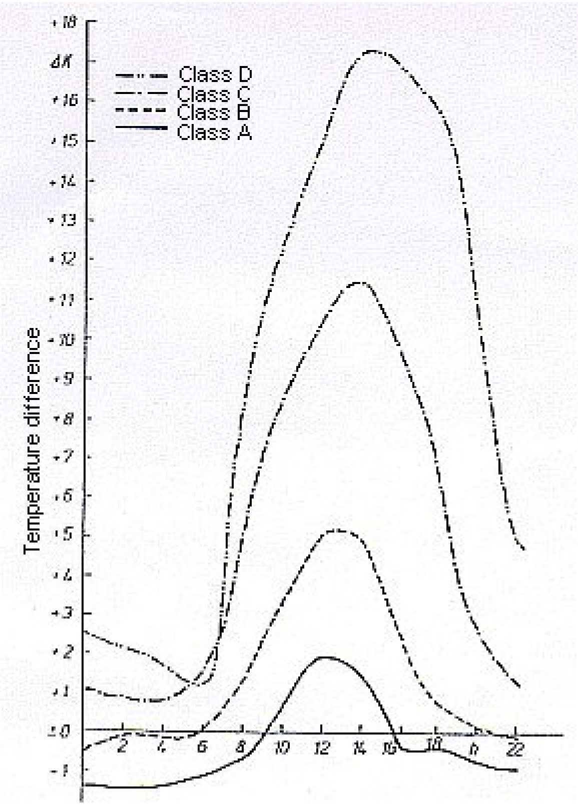


Figure 11: Average daily variation in overheating of the air inside a container, plotted by radiation class; Svenson [54]

10.3.2.2 Depth of penetration of temperatures

The influence of temperature variations of the container walls and of the air in the container on the temperature of the goods is a significant factor in storage.

Fig. 12 shows the daily amplitude in goods temperatures measured within the stack of a container packed with sugar on a sunny day in June: the daily amplitude in the interior of the stack is only 1.2°C, while that for the superficial layer is 6.3°C (see Fig. 12).

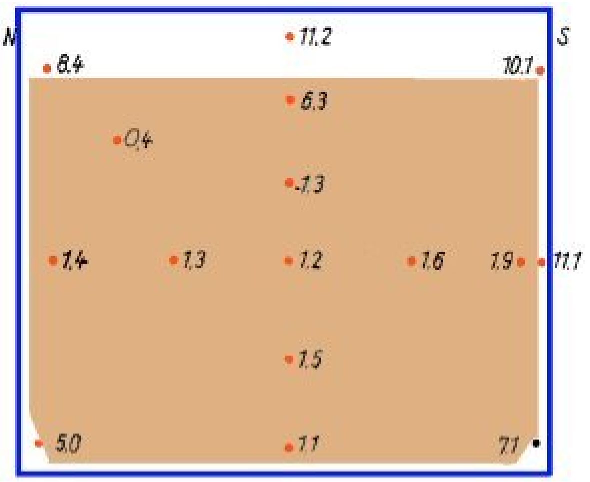


Figure 12: Temperature differences over 24 hours within the stack of a container packed with sugar in sales packaging;
U. Scharnow [42]

This means that the temperature in the interior of a stack of cargo adapts to changing external temperatures only very slowly. It is clear from these measurements how far the interior temperature of the goods lags behind changes in external air temperature caused by changes in weather conditions (see Fig. 13).

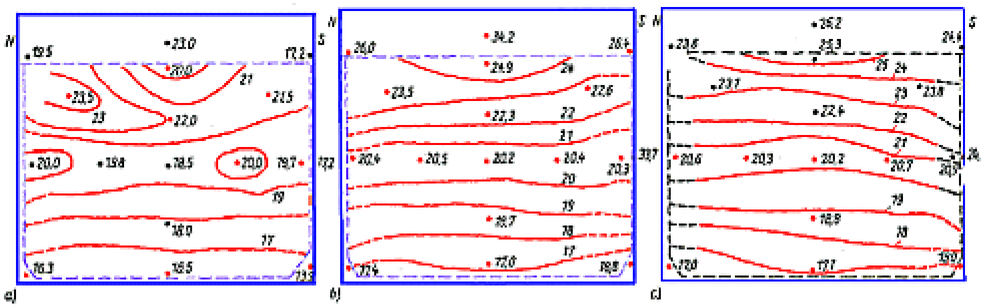


Figure 13: Measured air and goods temperatures at different times of day in a container packed with 16 metric tons of white sugar on a sunny day in June a) at 06:00, b) at 14:00 and c) at 18:00;
U. Scharnow [42]

The exposure of the goods to thermal stresses is determined by the size of the stack and its internal compactness. Stacks which are so dense that the ambient air cannot freely circulate within the stack do not readily adjust to external temperatures and water vapor also cannot be dissipated. Considerable delays may be observed even with this comparatively small stack in the container. The daily variation in temperature of a packed cargo is less marked. Although none of the cargo is more than 1 m away from a boundary surface of the cargo stack, the daily variations in air temperature in the container have, as can be seen, only a very gradual impact on the daily variation in goods temperature in the interior of the stack.

A different temperature regime is to be anticipated in a container which is completely filled with goods than in an empty or partially filled container.

Fig. 15 shows, for example, the frequency distribution of overheating in two differently loaded containers. While M 11 was obtained in a container packed with 16 metric tons of sugar (see Figs. 12 and 13), M 2 was simultaneously obtained in a container packed with 1.75 metric tons of bagged sawdust (see Fig. 15) which occupied approx. 30% of the container volume. The differences in humidity were still more extreme. While the sugar container did indeed also constantly exhibit comparatively high relative humidities of 70 - 80%, no appreciable sweating occurred and, after 6 months' storage, the sugar was unpacked again in perfect condition, whereas severe sweating was constantly observed in the sawdust container.

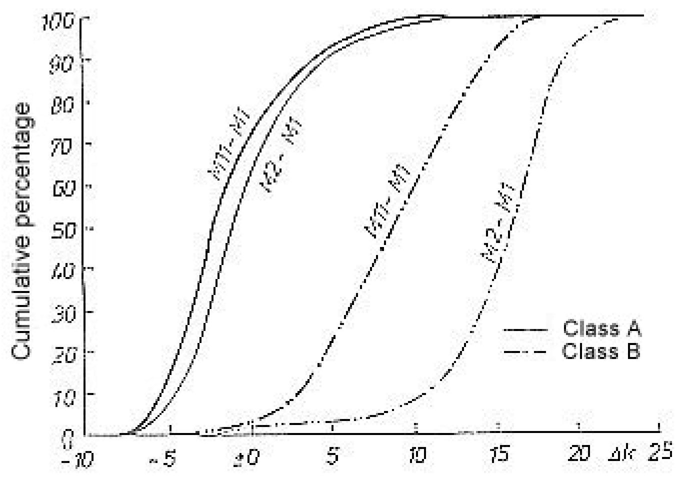


Figure 15: Frequency distribution of overheating in two differently loaded containers;
U.Scharnow/Svenson [41]

10.3.3 Water vapor in the container

Water vapor conditions in the container are primarily determined by internal factors, i.e. the water vapor conditions are largely determined by the hygroscopic properties of the cargo inside. The quantity of water vapor contained in the air is small and does not generally result in sweat damage. However, it may lead to other damage, e.g corrosion of metal goods.

Relatively large quantities of sweat in closed containers are always attributable to the cargo or its packaging (and/or the container floor if wooden). Sweat is thus actually possible only if water enters the container with the cargo. High air temperatures in the container and the associated low relative humidity drive water vapor out of the hygroscopic cargo. This water vapor condenses on the container walls and ceiling which is cooled by nocturnal radiation. Investigations reveal among other things that, starting with a dry container ceiling and side walls, sweat coverage increases in stages and reaches a maximum after a few days.

10.3.4 Sources of sweat

The following sources must be taken into consideration with regard to sweat formation in the container:

- the water vapor content of the air in the container
- the water vapor content of the air supplied by ventilation
- the water content of the cargo
- the water content of packaging, accompanying material and dunnage
- rainfall during loading
- penetration from outside where containers are damaged

10.3.4.1 Container air as source of sweat

The water vapor content of the air in the container can only result in small quantities of sweat, above all because as a rule the container is for the most part filled with cargo.

In a 20' container with a capacity of 33.14 m³, which is filled with air at a temperature of 25°C and with a relative humidity of 80%, only 0.611 kg of water is released when the air cools to 10°C.

This, distributed finely over the surface of the cargo, cannot wet the cargo but may be the cause of corrosion and other lasting superficial damage.

10.3.4.2 Ventilation air as source of sweat

If actively ventilated containers are available, which is becoming rare, relatively large quantities of water may enter the container as a result of excessively moist air being used for ventilation. If air is changed four times per hour, 1,060.5 m³ of air are passed through an identically sized container in eight hours of ventilation. If this air, at a temperature of 25°C and a relative humidity of 90%, meets with a cargo at 15°C, it cools down on the cargo and could theoretically deposit 9,757 kg of water, or almost 16 times as much. In practice, not the entire quantity of water will be condensed out, since the cargo warms up slowly and the air introduced does not mix very well and is therefore not completely cooled down.

A theoretical examination reveals very clearly the moisture potential of active ventilation.
10.3.4.3 Water content of the goods as source of sweat

A determining factor for the cryptoclimatic conditions in the container is the type of cargo with which the container is packed, the mass of the cargo and the surface area of the cargo readily accessible to the air also being of significance.

Hygroscopic cargoes largely determine the water vapor balance in the container due to their sorption behavior by adjusting the relative humidity of the residual air to the cargo's particular equilibrium moisture content.

The quantities of water which can be released by goods of vegetable origin are still greater. The shrinkage/shortage of goods of vegetable origin arising as a result of evaporation may amount to up to 0.5% of mass depending on the water content of the cargo on loading.

The optimum water content of cocoa beans is between 5 and 6% (see Fig. 16). The higher the actual value is above this, the greater is the tendency of the cargo to release water vapor into the container air.

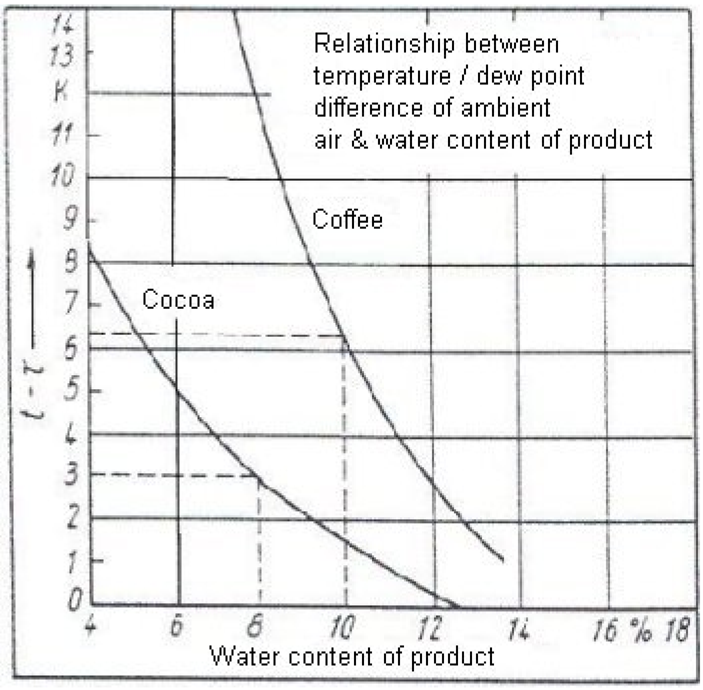


Figure 16: Sorption isotherms for coffee and cocoa beans showing the limits of "container dry" water content;
Svenson [55]

This water vapor would have to be dissipated, which is impossible in standard containers, being an option which is available only with passively ventilated containers (coffee containers).

The risk of cocoa beans and other goods of vegetable origin absorbing a lot of moisture, on the other hand, is particularly great in the rainy season, making the transport date particularly significant. Goods of vegetable origin are the most intensive source of sweat in a container. These goods are most at risk with regard to hold meteorology. It is impossible to remove such quantities of water from the container by ventilation.

A determining factor for the cryptoclimatic conditions in the container is the type of cargo with which the container is packed, the mass of the cargo and the surface area of the cargo readily accessible to the air also being of significance. Hygroscopic cargoes largely determine the water vapor balance in the container due to their sorption behavior by adjusting the relative humidity of the residual air to the cargo's particular equilibrium moisture content.

By way of example, dolls were gift-wrapped and packed in shipping packages in an excessively moist state. As temperatures fell during the voyage from the Far East to Northern Europe, the relative humidity inside the gift

wrapping rose to saturation point, leading to soaking and mold. The result was a total loss, since the mold needed to be removed, and the dolls dried and repackaged (see Fig. 17).

Care must always be taken to ensure that the cargo is packed into the container in a container dry state.

Figure 17: Mold damage on cargo that was not container dry; Photo: Scheen [48]

10.3.4.4 Water content of packaging, accompanying material and dunnage as source of sweat

Packaging and dunnage may also be sources of relatively large quantities of sweat. If a container carrying 20 metric tons of general cargo contains 2 metric tons of wooden dunnage and case lumber and if this has a water content of 30% instead of the usual 15%, the packaging alone introduces 0.6 metric tons = 600 kg of water into the container. Such large quantities of water occur in the case lumber if the lumber is too green or the cases were stored in the open air and soaked with rain.

These 600 kg of water evaporate (desorption) until the container air is saturated with water vapor (100% relative humidity). During the night, the container cools down and the air can no longer "hold" the water vapor, condensation therefore appearing on the container ceiling and wall (container sweat). The quantities of condensation may be so great that it actually "rains". This process may be repeated day after day. Its intensity depends, among other things, on temperature differences, which may increase when passing from one climatic zone to another.

10.3.4.5 Rain water (leaks) as source of sweat

Downpours (especially tropical) can also soak the goods with considerable quantities of water, especially when they are stored in the open air under inadequate covers and during packing and unpacking of the container. Enormous amounts of rain may fall in tropical downpours, for instance more than 2 mm per minute. During the voyage, evaporation again occurs, along with condensation on the cargo and the container walls.

Container leaks must always be expected. The roof, floor and container door areas are particularly likely to leak.

If the spreaders are not positioned accurately, they may be set down on the container roof next to the corner castings. Setting down of a spreader on the container roof may be done very roughly, resulting always in the risk of direct damage and subsequent rusting through. If this happens repeatedly, the container roof may suffer serious damage, resulting in leaks, especially at the points which have by then rusted through.

Forklift trucks may cause the container to bulge upwards and these points then corrode, leading to leaks in the floor area.

Leaks frequently occur in the container door area. By way of example, the doors of a refrigerated container warped as a result of damage to the container roof, so that rainwater could get in, forming a layer of ice in the area of the doors.

However, leaky rubber door gaskets on refrigerated containers may also allow rainwater to enter in the door area, forming a layer of ice.

Leaky doors on standard containers have also resulted in mold damage to malt which was being transported from Europe to Japan as a deck cargo. This was dealt with by fitting a plastic curtain to protect the container doors from moisture penetration.

10.3.5 Influence of radiation on container cryptoclimate

10.3.5.1 Formation of container sweat in radiation weather

10.3.5.2 Sweat classes

Reported cases of sweat damage in containers show that all three of the main processes of sweat formation may occur in closed containers, these being:

1. Container sweat in radiation weather
2. Condensation on the container wall, i.e. "container sweat", during voyages with a drop in air temperature due to changing climatic conditions.
3. Formation of cargo sweat during voyages involving a rise in air temperature and dew point temperature of the external air due to changing climatic conditions, where the external air is able to penetrate the container or in the case of open containers

10.3.5.1 Formation of container sweat in radiation weather

Intensive formation of container sweat is to be expected in radiation weather in a closed standard container packed with hygroscopic goods. The daily cycle of heating up of the air in the container through the overheated roof and walls and cooling of the same during the night encourage the release of water vapor, which leads to sweat formation in the event of cooling. Stable stratification of the air and the absence of any forced circulation in the closed container may lead to the accumulation of sweat on the ceiling and finally to dripping.

Investigations by the hold meteorology study group reveal among other things that, starting with a dry container ceiling and side walls, sweat coverage increases in stages and reaches a maximum after a few days. The interaction of all the various factors leads to the following presumed mechanism for the formation of sweat in the container: during heating of the container surfaces and thus also of the internal air and the cargo surface, the relative humidity of the container air falls. The container floors and the cargo release water vapor into the ambient air in accordance with their temperature and with desorption characteristics. The absolute humidity of the internal air increases. Through further heating of the container air, the relative humidity falls further. In the event of heating to a maximum temperature of 50°C, the residual air quantity in the container could absorb approximately 1,800 g of water vapor. However, the actual quantity is lower, since water vapor saturation of the air is not reached during the heating process. The water vapor emitted into the air is supplied by the surface layers of the cargo, i.e. the vapor pressure also drops inside the stack and thus moisture flows from the interior to the outside of the cargo. Such moisture is easily detected. Thus, given an average sweat coverage of the container surface, the water content of the cargo ought to have fallen by approximately 0.64%. However, the water content of the surface batches was actually observed to drop by several percent. This process is illustrated in Fig. 18.

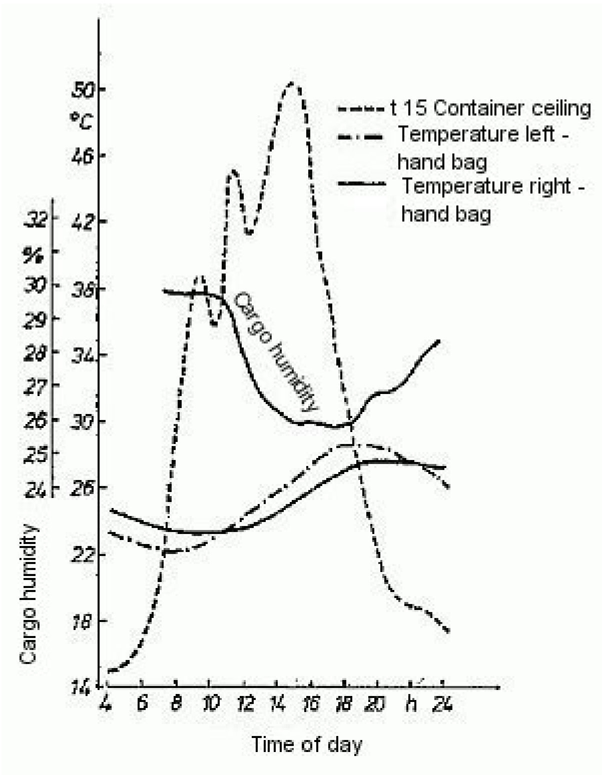
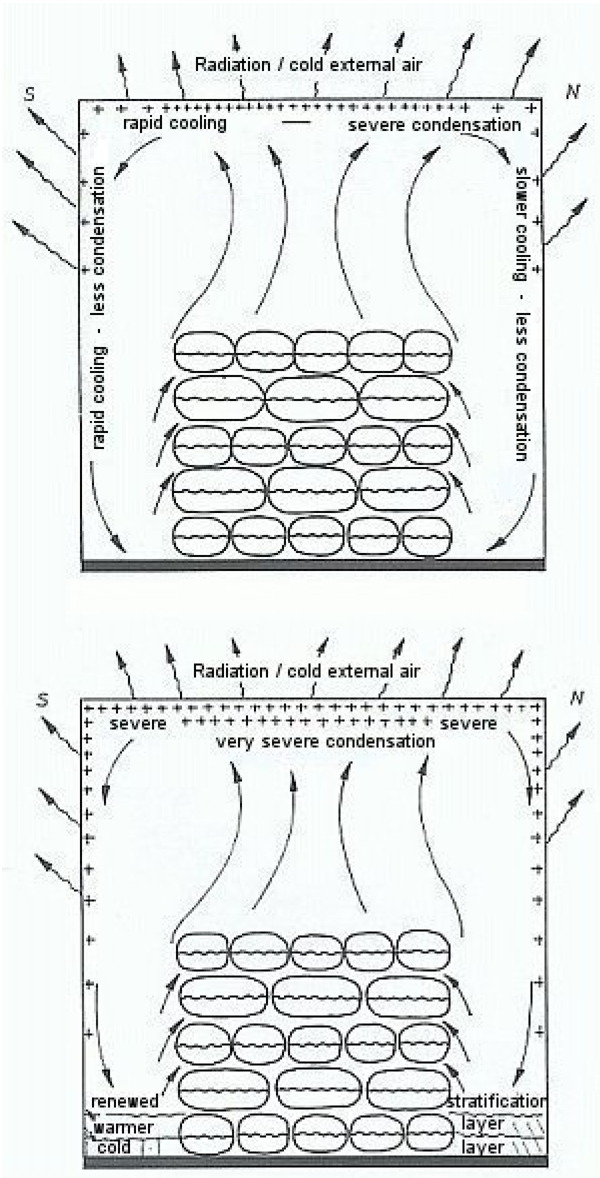


Figure 18: Temperature and water content of the product surface and ceiling temperature of the container on a sunny day;
Svenson [54]

If the container heating maximum is exceeded, the temperature of the container air falls and the relative humidity rises. An essential factor is that the cargo absorbs water vapor very much more slowly ("adsorption retardation"), as a result of the moisture flow in the cargo itself and the later arrival at the cargo temperature maximum.

Part of the water vapor condenses on the cooling container walls as soon as their temperature falls below the dew point temperature of the internal air. Sweat starts to form on the ceiling and the vertical walls. When heating next occurs, part of the water vapor absorbed by the internal air is supplied by the sweat on the vertical walls. To bring

about a vapor pressure equilibrium between cargo and air, the cargo needs to emit less water vapor. Due to the stable air stratification which occurs, the sweat on the ceiling does not come into thermal contact with circulating air and can only develop by diffusion into lower, drier masses of air (see Figs. 19, 21 and 22). This process proceeds more slowly than the absorption of evaporation sweat by the drier air flowing past the vertical container surfaces. Under the container ceiling, the sweat does not dry off despite considerable overheating of the roof. This water is replaced by further desorption from the cargo. Thus, the quantity of sweat on the container surfaces increases in stages from day to day, until a maximum is reached. This can only be dealt with by destroying the stable air strata in the container by active ventilation, for which the ventilation openings present are inadequate, however.



1st phase:
pure stratification (vertical cooling)

2nd phase:
exchange within neighboring layers starts
(horizontal cooling)

Figure 19: Sweat formation under the ceiling of the container in radiation weather;
U. Scharnow

Fig. 19 shows clearly that the majority of the sweat is on the container ceiling. This fact is of particular significance because sweat on the wall can run off without causing major damage, while sweat on the roof drips directly onto the stored cargo and so constitutes the greater risk.

Another conclusion which may be drawn is that more sweat is formed as radiation conditions improve. Goods packed in a container are exposed to a much lower level of risk under conditions with little radiation than under good radiation conditions.

In the case of a closed standard container, the following loss prevention measures are recommended for safe transport:

- keep the water content of the cargo, packaging and container floor low, since this makes for less intense sweat formation

* protect the cargo from dripping water
* choose the stowage space in such a way that the containers are not exposed to any radiation
* leave ventilation openings open or choose ventilated containers, so that warm air with a high water vapor content is dissipated

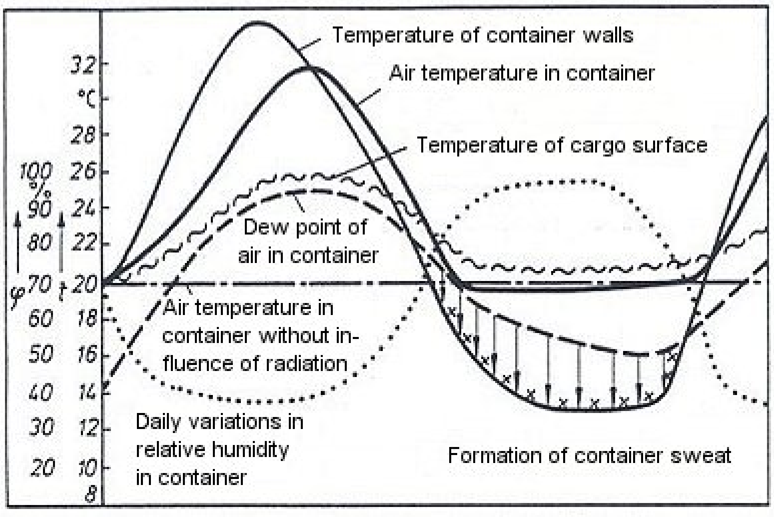
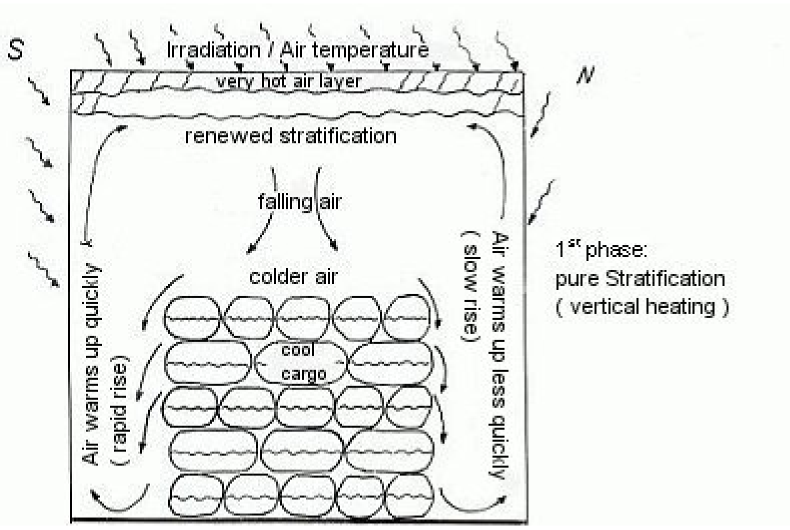


Figure 20: Schematic representation of the daily variations in the air, dew point and interface temperatures and the container sweat they bring about;
U. Scharnow [43]

Figure 20 is a schematic representation of the daily variations in the air, dew point and interface temperatures which determine the storage climate and the formation of container sweat such variations cause, leading to the following conclusions:

The most persistent sweat formation in the container takes place during radiation weather, if the container is exposed to direct solar radiation during the day and is subject to outward radiation at night. Intensive heating of the air leads to a reduction in the relative humidity in the container, encouraging water vapor release from the cargo. The dew point of the air in the container rises. After sunset cooling occurs. If the temperature of the container falls below the dew point of the air in the container, condensation arises on the container ceiling and walls. Next day, the water condensed on the walls dries up again, but not the water under the container ceiling, which remains there as a result of stable stratification and increases day by day until it starts to drip (see Figs. 21 and 22).



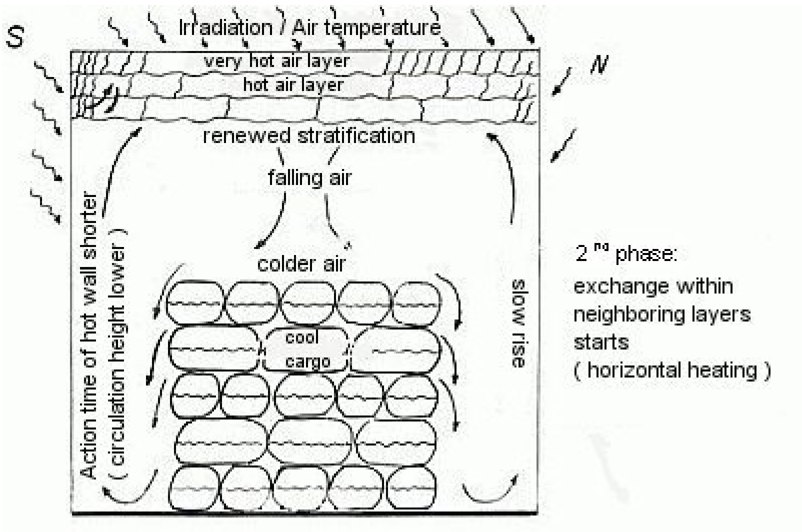
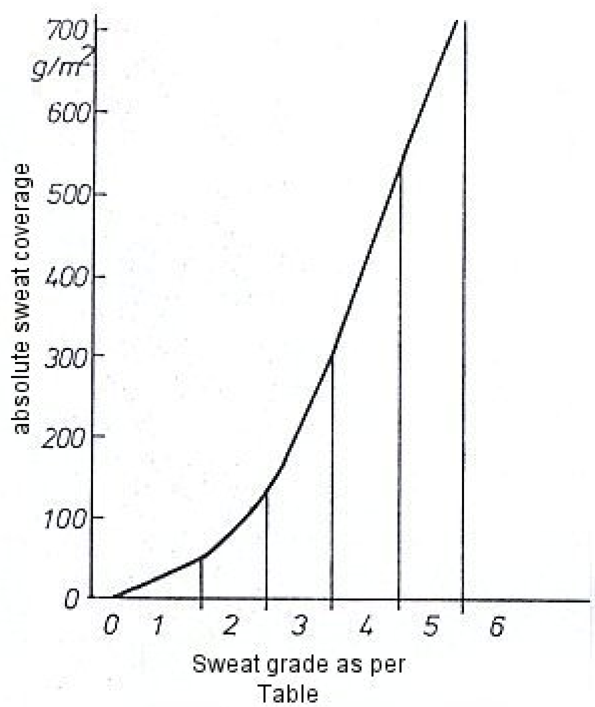


Figure 21 (top) and 22: Formation of container sweat in radiation weather; Svenson [54]

10.3.5.2 Sweat classes

Series of measurements carried out in the hold meteorology study group at the Warnemünde-Wustrow University of Seafaring demonstrated that such condensation is most severe on the container ceiling and that, despite strong heating due to solar radiation, drying does not occur during the day, as may regularly be observed on the walls, and the quantity of sweat builds up after a few days to such an extent that the water drips off and falls onto the surface of the cargo.



Tabulated grades	Range
0	0 = dry
1	0-40 gm^{-2}
2	40-120 gm^{-2}
3	120-300 gm^{-2}
4	300-540 gm^{-2}
5	540-760 gm^{-2}
6	760 gm^{-2} and above

Figure 23: Absolute quantity of sweat in g/m² according to sweat classes; Svenson [54]

Fig. 23 shows the determined absolute quantities of sweat in g/m² according to sweat classes, i.e. the number of

grams of sweat present on one square meter of surface at the individual classes. Table 1 shows the observation features for classification of sweat classes. The loss adjuster can use these features to make a good assessment of sweat damage.

Class	**Feature**	**Quantity of water in g / m²**
0	No sweat	0 dry
1	Surface feels moist (not just cold).	0 - 40
2	Sweat can be swept together with the hand and then runs off.	40 - 120
3	Distinct droplets formed. Individual droplets run down vertical walls.	120 - 300
4	Surfaces densely occupied with large droplets, which frequently run off vertical surfaces	300 - 540
5	Isolated dripping from the ceiling, constant run-off from vertical surfaces	540 - 760
6	Severe dripping from ceiling, puddles formed at the bottom of vertical surfaces	760 and above

Table 1 shows the observation features for classification of sweat classes;
U. Scharnow

Fig. 24 shows sweat formation on a container ceiling. The differences in sweat formation of the individual boundary surfaces depending on their exposure and the variable occurrence of sweat classes under different radiation conditions are of particular significance.

Figure 24: Container sweat: sweat class 4;
Photo: Schieder [18]

See in this connection Fig. 25, which shows the percentage frequency of the occurrence of sweat classes on the individual boundary surfaces of the container. The most remarkable features are the extremely high percentage of the occurrence of sweat on the container ceiling, together with the extremely low percentage frequency of occurrence of sweat class 0. The Figure also shows, for example, that the south wall of the container exhibits the lowest risk of sweat formation. This is manifested in that sweat class 0 is found to occur most frequently in both classes on the south wall, while distinctly lower frequencies are observed for the higher sweat classes. On the basis of the distributions shown here and of other investigations, it is clear that the greatest quantity of sweat always occurs on the container roof. This also tallies with investigations into the mechanism of sweat formation in containers. This fact is of particular significance because sweat on the walls can run off without causing major damage, while sweat on the roof drips directly onto the cargo and so constitutes the greater risk.

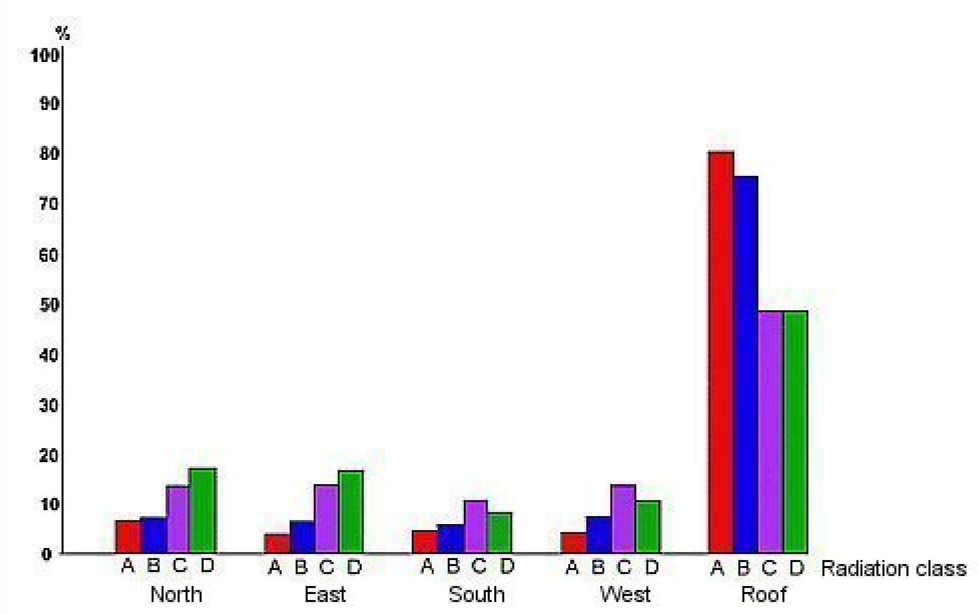


Figure 25:
Frequency of occurrence of sweat on the boundary surfaces of a container;
U. Scharnow

Another conclusion which may be drawn from Fig. 25 is that more sweat is formed as radiation conditions improve. Goods packed in a container are exposed to a much lower level of risk under conditions with little radiation than under good radiation conditions.

The moisture equilibrium, which may also be stated as the temperature/dew point difference (see section 10.2.6), is a significant factor in sweat formation. If the equilibrium moisture content of the product is low, for example at 60% relative humidity, the air temperature/dew point difference is approx. 8°C, i.e. nocturnal cooling of the container wall must be 8°C for the air temperature at the container wall to fall below the air's dew point. At a higher equilibrium moisture content, for example of 75%, a drop in temperature of 5°C is sufficient to trigger condensation.

Since the equilibrium moisture content is a function of the product's water content, it is consequently important to pack hygroscopic goods into the closed container in the driest possible state (container dry). The lower is the water content of the goods packed, the lower too is its tendency to form sweat in the container.

There is a risk of sweating if containers are transported from a warm region into a colder climate and are not rapidly unpacked. For example, three containers packed with coffee at the cargo temperature of 18°C were unpacked at different times while the external temperature was close to 0°C. The first container was opened immediately and emptied. It had severe sweat on the ceiling, which was also dripping down, but the coffee suffered no damage as a consequence.

The second container was unpacked one day later and exhibited considerable sweat damage taking the form of a soaked uppermost layer.

On the third day, the third container was unpacked: the contents were severely soaked and there was distinct mold growth.

Fig. 26 shows the measured sweat coverage in a standard container exposed to radiation in high summer in Central Europe at depths of 0 - 40 cm; from a level of 300 g/m² in the topmost centimeters, coverage drops to 0 - 40 g/m² at a depth of greater than 25 cm.

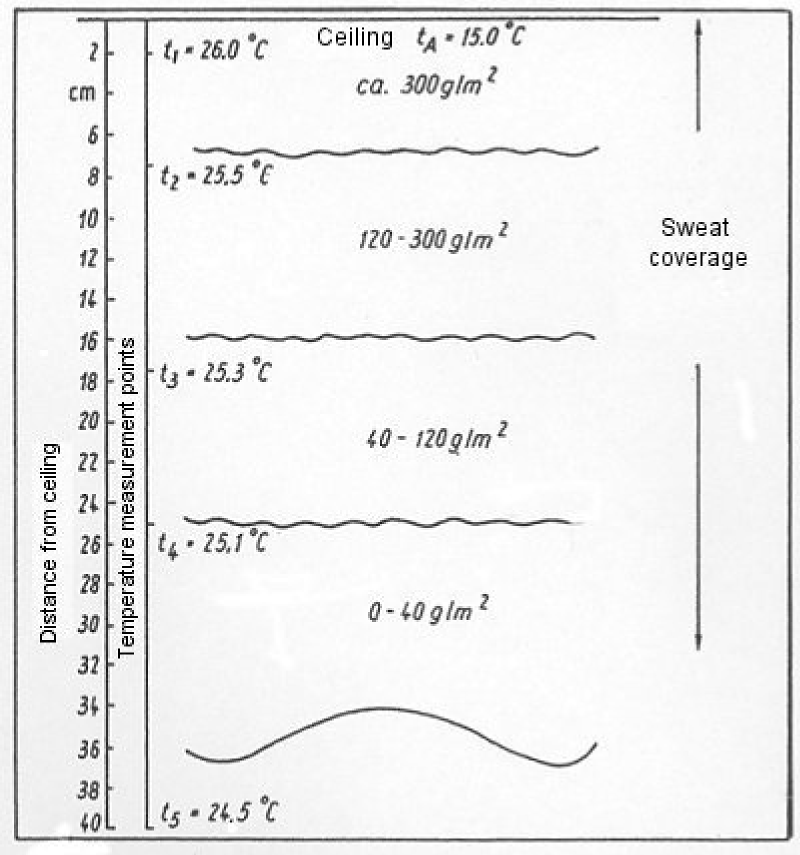


Figure 26: Measured sweat coverage in a standard container exposed to radiation (Central Europe, high summer);
Svenson [55]

The following loss prevention measures are recommended to avert sweat damage:

- unpack container quickly if the cargo temperature is still higher than the external temperature
- lay paper dunnage in order to absorb sweat
- lay out a plastic sheet with a condensation reservoir, fix some nonwoven fabric in place
- provide desiccants

10.3.6 Influence of climatic change due to international transport

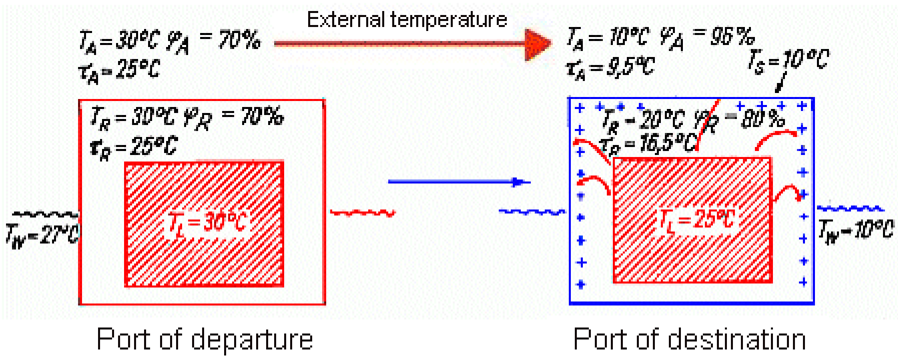
Sweat damage accounts for a considerable proportion of total container losses and this proportion is on the increase, so we will take a particularly close look at this kind of damage in this section.

The following comments relate to a closed standard container packed with a hygroscopic product or with goods of vegetable origin with a high water content, such as fruit or the like.

10.3.6.1 Formation of container sweat in the event of a drop in air temperature due to sea route: voyage into temperate latitudes

One source of sweat is the proportion of the product which is constituted by water. goods of vegetable origin, such as coffee, rice, cereal products, lumber products together with citrus and other fresh fruit, release water vapor into the container air while in transit. On the basis of their water content and biotic activity, they establish an equilibrium moisture content. If, during the voyage, the container wall is cooled by the external air to below the dew point temperature of the internal air, sweat starts to form on the walls. The intensity of sweat formation depends, on the one hand, on the position of the moisture equilibrium, i.e. the air temperature/dew point difference in the container and, on the other, on the daily drop in air temperature, with nocturnal radiation from the container walls also being of particular significance. This process begins as soon as the ship leaves the subtropics in winter and may become particularly intense in frosty weather as the goods still store considerable quantities of heat which maintain thermal circulation, by means of which water vapor is constantly transported from the goods to the container ceiling.

Fig. 27 shows container sweat at low external air temperatures. In freezing weather, condensation may also be accompanied by immediate formation of ice or sublimation (transition from the solid to gaseous state without passing through the liquid state), so still further promoting the build-up of water on the ceiling because, when the temperature rises, instead of evaporating, the water drips down and causes wetting damage on the surface of the cargo.



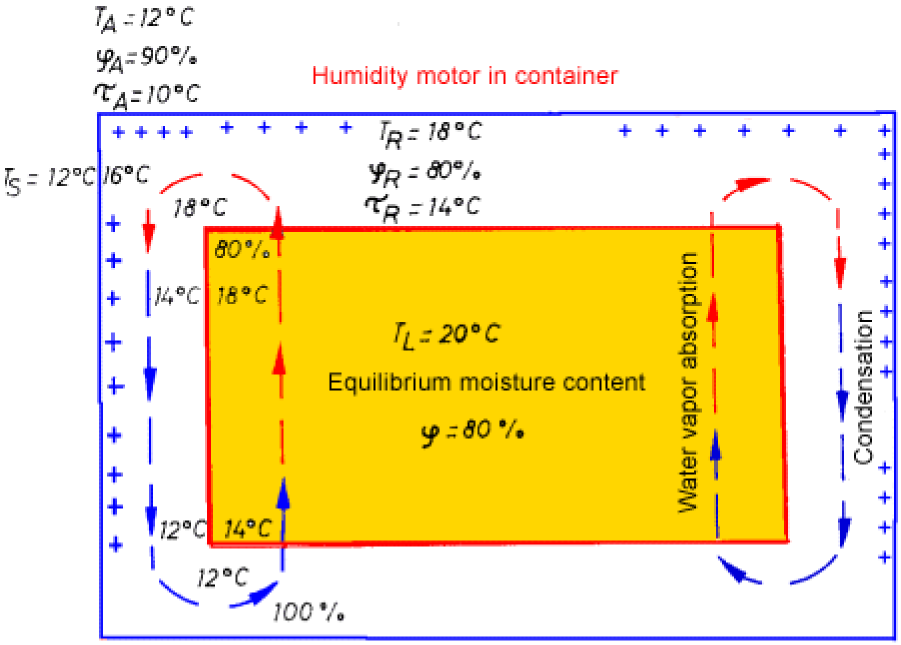
T_A - temperature, external
T_W - water temperature
T_L - cargo temperature
φ_A - rel. humidity, external
T_R - hold temperature
τ_A - dew point, external
τ_R - dew point, hold
T_S - temperature of side wall

Figure 27: Formation of container sweat in the event of a drop in air temperature due to sea route: voyage into temperate latitudes;
U. Scharnow [46]

Excessively rapid cooling of the outer layers of the stack may also result in wetting damage. In this case, condensation occurs within the stack on the cold, outer layer of the cargo stack. The effects of this are particularly disadvantageous for the goods. In bagged cargo, such damage is observed directly beneath the upper layer of bags, which appear to be dry from above. The damage is revealed when the first bags are lifted.

10.3.6.2 Humidity motor (cycle) in the container

The intensity of container sweat is determined by the temperature gradient between the cargo and container wall. If this gradient is steep and ventilation is not possible in the standard container, a humidity motor (cycle) is formed, as is shown in Fig. 28. The temperature of the external air is 12°C and the temperature of the cargo 20°C.



T_A - temperature, external
φ_R - rel. humidity in hold
T_L - cargo temperature
φ_A - rel. humidity, external
τ_R - dew point, hold
τ_A - dew point, external
T_R - hold temperature
T_S - temperature of side wall

Figure 28: Humidity motor (cycle) in the container between the cargo and the container wall; U. Scharnow [46]

During thermal circulation, the container air cools down to below its dew point on the container wall and a proportion of the water vapor condenses because the temperature is below the dew point. As a result of the thermal circulation, this air returns to the cargo, where it warms up and picks up water vapor, before cooling back down again on the container wall.

10.3.6.3 Loss prevention measures

1. Hygroscopic goods must have the lowest possible water content when they are packed in the container. Where there is no experience for a particular product, it is advisable to comply with the lower water content limit which is provided for transport in conventional holds. If a water content of 10 - 12% has in the past been recommended, the goods should be packed at 10% and below (see TIS, where the upper and lower temperature limits are stated). However, caution is required in that an excessively low water content may result in impairment of quality, such as drying-out of tobacco, cracking of lumber or loss of aroma in spices. One vital factor is the size of the temperature/dew point difference of the equilibrium moisture content, which should be > 6°C. Water content cannot be reduced for fruit and vegetables. They must be packed at the lowest possible temperature and should always be kept away from solar radiation.

2. It must be possible to cool the goods rapidly in the container, with the mass of the cargo in the container and the accessibility of the surfaces to the air playing a major part, in order to improve the transfer of heat from the cargo to the container wall.

3. Where the possibility of sweating during the voyage is suspected, the surface of the cargo should be protected from dripping water. Paper and gunny cloth are more suitable than plastic sheet, as using the latter may simply move the condensation surface to the underside of the sheet, resulting in the sweat coming into direct contact with the cargo. Relatively large quantities of sweat may, however, only be kept away from the cargo with nonwoven fabric.

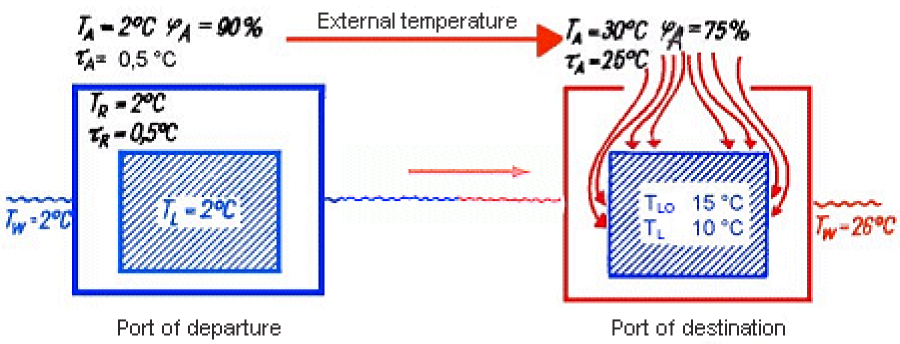
4. Using an anticondensation film, one ply of which is highly impermeable to gas and vapor while the other is capable of absorbing up to 150 g of water per m², would also be favorable.

5. Containers packed with hygroscopic goods or fruit and vegetables should be transported below deck, as the temperature of the air and thus of the container walls drops substantially more gradually here and heat may be dissipated by vigorous ventilation or, in the event of a major drop in air temperature, ventilation may also be turned down.

6. It is necessary to cool the containers as they are always kept and transported in the open at the port of destination, so that containers with a hygroscopic cargo and at a high temperature are at extreme risk. The doors may, if necessary, be opened in the port, so immediately suspending the formation of container sweat.

10.3.6.4 Formation of cargo sweat in the event of a rise in air temperature due to sea route: voyage into the tropics

Cargo sweat occurs if the temperature of the surface of the cargo is lower than the dew point temperature of the external air ($T_{LO} < \tau_A$). The closed standard container under consideration here (see Fig. 29) provides the considerable advantage that the external air has only little access to the cargo in the container.



T_A - temperature, external	T_R - hold temperature
T_W - water temperature	τ_A - dew point, external
T_L - cargo temperature	τ_R - dew point, hold
φ_A - rel. humidity, external	T_{LO} - cargo surface temperature

Figure 29: Formation of cargo sweat in the event of a rise in air temperature due to sea route: voyage into the tropics;
U. Scharnow [46]

However, in this case it is important not to underestimate the level of air exchange through the small ventilation openings and leaks at the doors which arise in strong winds. This air exchange is sufficient to initiate corrosion processes and other physical, chemical or biotic processes in goods, such as granulated sugar in bags, cement, chemicals etc., which have already been detrimentally affected by slight moisture deposits. In such cases, these openings should be closed (use of sealants) and care should be taken to seal the doors well, as many of these goods create their own cryptoclimate which is perfectly suited to storage.

The possibility of stopping air exchange also creates the conditions for new transport operations which would not hitherto have been contemplated or were associated with considerable risk, e.g. transport of white sugar from Europe to the tropics in the winter. On unpacking, it was found that the sugar had released moisture from the inside outwards onto the bags (jute bags) in which it was wrapped and the surface had caked, i.e. become hard. This pattern of damage may be explained as follows.

On relatively long voyages, the inner bags of the stack remain cold for longer; due to the different sorption behavior, water vapor is conveyed from the warmer outer sugar to the colder sugar inside the stack. This resulted in water stains on the sugar bags of the cold cargo core, while the outer bags became caked.

Goods which are stowed in the container as a large block cannot warm up over the course of a voyage of just a few days. Ventilation conditions are not provided. On unpacking, the bags become wet due to condensation of the warm, moist tropical air on the still cold bags, before they can be handed over to the receiver.

The container should not be opened immediately at the port of destination. The cargo, which is sealed off from the external air virtually hermetically, then has time to adjust to the temperature level of the port of destination.

10.3.6.5 Loss prevention measures

The following cargo care measures are recommended for standard containers for a transport operation involving a rise in air temperature due to sea route:

1. When packing such a container, good air circulation must be ensured between the container surfaces and the cargo surfaces, so that rapid thorough heating of the cargo is possible.

2. In the case of goods which release larger amounts of water vapor, pay attention to radiation.

3. Selection of an optimum stowage space:

    - On deck, to achieve rapid heating of the container and its contents, stow where possible away from radiation in the inner layers of the deck cargo

    - In the case of shipment below deck, ventilate intensively to heat the containers and their contents; sweat arising on the outside of the container is harmless, provided that the container arrives dry on the outside at the port of destination.

4. Containers at particular risk (first port of destination or immediate unpacking of container contents at port) should be positioned in the immediate vicinity of the fan outlets or in places near heated double bottom cells or bulkheads.

    If the containers are to be inspected in port, e.g. by customs officers, the container should be opened only briefly or under a plastic shroud, since otherwise in sub-tropical ports the surface of the cargo immediately becomes moist, leading as a rule not to cargo sweat but to claims.

10.3.6.6 Route from Rostock to West Africa and the formation of cargo and container sweat

Fig. 30 provides an overview of the variation in air, water and dew point temperature on the route from Rostock to West Africa and the anticipated temperatures of the cargo in the container on a ship making an outward and a return voyage in the month of November.

The external air temperature (T_A) was taken from a measurement series from a ship in transit, while water temperatures and their changes were brought into line with existing measurement series in order to reveal the interrelationships:

1. On the outward voyage, the air temperature rises from 4°C in Rostock to 26°C in Conakry. The temperature of the cargo surface (T_{LO}) rises from 2°C to 16°C. Cargo sweat must be expected on the "outward voyage", because the surface temperature of the cargo is lower than the dew point of the external air ($T_{LO} < \tau_A$).

2. On the return voyage, the external air temperature drops relatively rapidly (> 6°/d) due to the distance traveled and the weather conditions, as a result of which the cargo in the container often cannot adapt rapidly enough to this change in temperature. Clearly, as the container is cooled in the external air to below the dew point temperature of the air (τ_L), container sweat is formed, especially on the container ceiling, from where, once sufficient sweat has formed, it drips down onto the cargo.

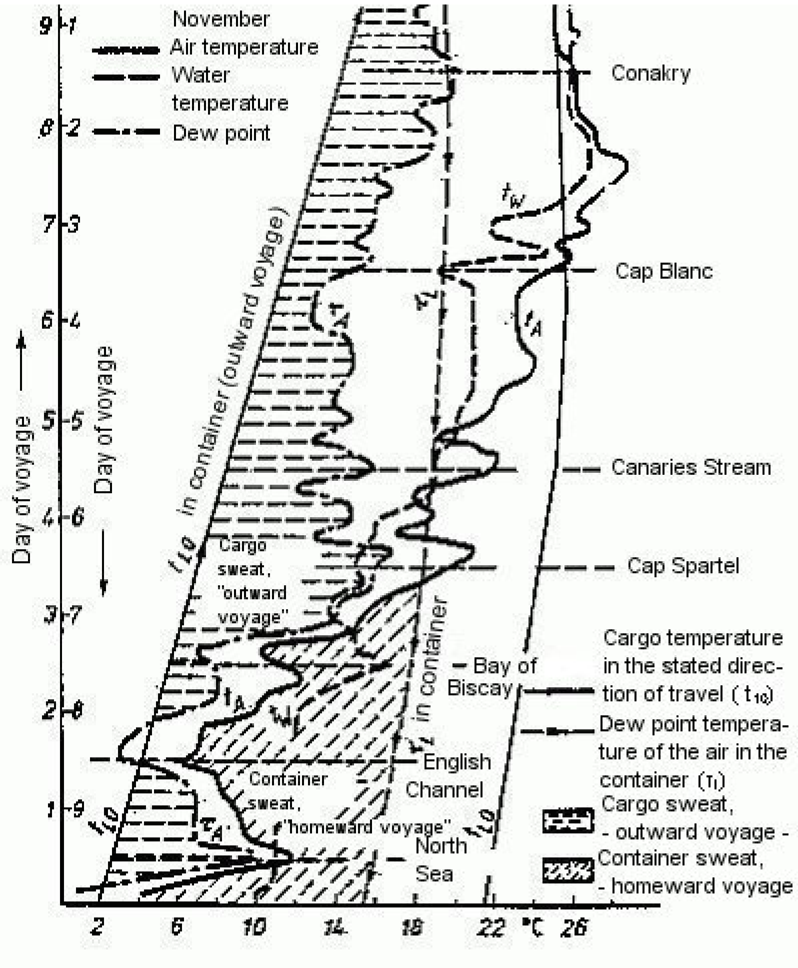


Figure 30: Variation in air, water and dew point temperature on the route from Rostock to West Africa and anticipated temperatures of the cargo in the container on a ship making an outward and a return voyage; U. Scharnow [43]

10.3.7 Loss prevention measures for avoiding moisture damage in container transport

1. It is essential that cargo, packaging, accompanying material and dunnage be packed into the container when container dry. The risk of mold growth on hygroscopic goods in sales packaging can be reduced by "ventilated", i.e perforated, packaging, e.g. the plastic film around rattan furniture is provided with holes.

2. If cartons, e.g. shoe boxes, are provided with ventilation holes, they only have an effect when the cartons with ventilation holes in their ends are stowed crosswise in the ventilated container.

3. Some products have fungicides in powder form mixed in with their dyes, to prevent mold growth. In this case, however, health protection measures are necessary.

4. If water-soluble adhesives are used for products such as toys, so much mold may develop that total loss ensues.

5. Covering the floor, sides and cargo surface with paper dunnage (see Fig. 31) provides a certain degree of protection against dripping sweat. The paper absorbs water until saturated, and if more sweat develops the water penetrates the cargo. Fig. 32 shows how the paper dunnage has become soaked, and Fig. 33 likewise shows how the corrugated board lateral dunnage has become soaked from the ceiling downwards.

Figure 31 (top left): Paper dunnage on cargo of bagged coffee;
Photo: Schieder [18]

Figure 32 (top right): Soaked paper dunnage;
Photo: Stradt [53]

Figure 33 (bottom left): Lateral container dunnage soaked from the ceiling downwards;
Photo: Stradt [53]

6. Another possible way of catching dripping sweat is to lay out a plastic sheet with a condensation reservoir (see Fig. 34). The moist warm air rises up past the sides of the sheet to the container ceiling, condenses there and drips onto the sheet. Up to 120 liters of water had already been caught in the reservoir in this way, but even this method is limited in its effectiveness.

For example, the sheet may be pulled over sharp edges and damaged due to the weight of the collecting water and to the movement thereof resulting from movement of the means of transport. If the puddles turn to ice in winter, the ice can virtually shred the sheet.

When using a plastic sheet instead of paper dunnage, consideration also needs to be given to the fact that the condensation surface may be moved to the underside of the sheet, resulting in the sweat coming into direct contact with the cargo.

Figure 34:
Plastic sheet;
Photo: Stradt [53]

7. More recently, nonwoven fabric with a relatively high water absorption capacity of up to 3,000 g/m² (3 liters/m²) has been suspended beneath the container ceiling (see Fig. 35).

It is attached to the cargo securing lugs beneath the container ceiling by means of cable clamps. Sagging of the nonwoven fabric can be minimized by special belts. With this method too, however, water may penetrate the cargo once saturation point is reached.

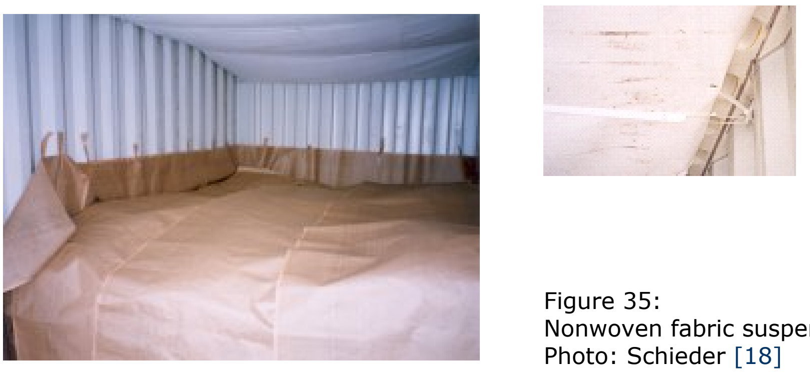


Figure 35:
Nonwoven fabric suspended in the container
Photo: Schieder [18]

8. When stripping hygroscopic goods, such as coffee or cocoa, in winter in temperate latitudes, quite large quantities of sweat may arise in a short time.
In such an instance, a nonwoven fabric may delay the time at which the still relatively warm cargo becomes soaked (see Section 10.5.1) enough to allow damage-free unpacking of the container.

9. The nonwoven fabric is suspended from the container ceiling corner reinforcements by means of belts (see Fig. 36). The water vapor absorption rate may amount to as much as 3,000 g/m². The nonwoven fabric may be cleaned for reuse.

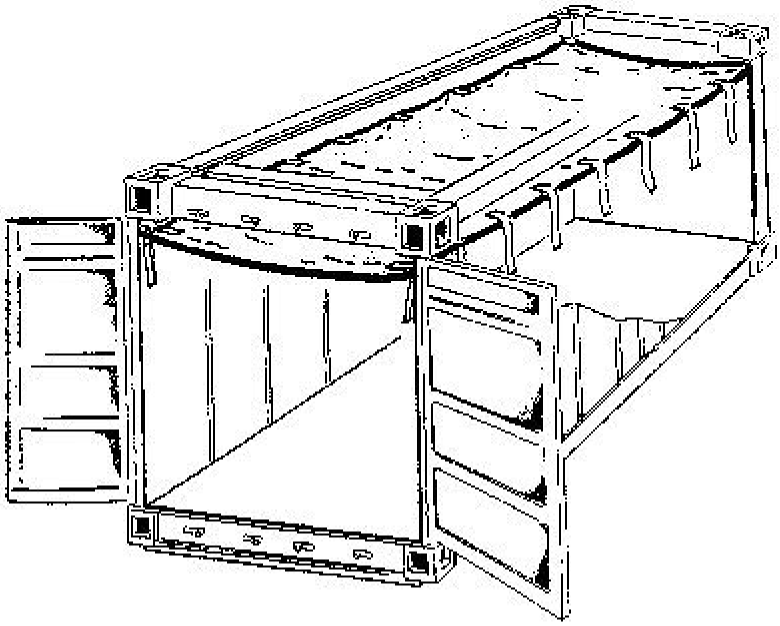


Figure 36: Nonwoven fabric for transport of moisture-sensitive goods, suspended from the container ceiling by belts;
Oellerking [10]

10. If bulk cargo is to be transported in a standard container, a "liner bag" made from a woven plastic fabric can be suspended in the container (see Fig. 37). Once the container is packed, the liner bag is closed with straps. The container is unpacked by cutting the liner bag open at the bottom and tipping the container. The liner bag is used only once.

Figure 37: Liner bag for bulk cargo in a standard container;
Photo: Schieder [18]

Hygroscopic bulk cargo can be transported in a standard container by means of a liner bag with built-in nonwoven fabric in the roof area (see Fig. 38).

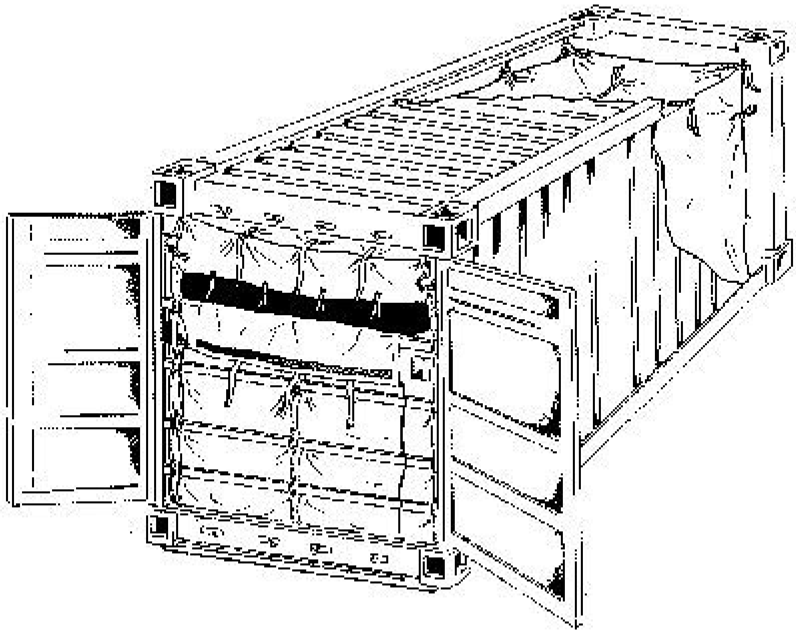


Figure 38: Liner bag for bulk cargo in a standard container;
Oellerking [10]

11. In order to transport high value industrial products, such as machinery, electronic equipment, measuring instruments and the like in a standard container without causing moisture damage, a sealed package is produced (see Fig. 39). For example, the machine is bolted firmly onto the case bottom and enclosed in a film which is impermeable to water vapor, taking care to ensure that no sharp-edged parts destroy the film. A sealed package can only be carried door-to-door in a FCL container, so avoiding additional transshipment operations, as there would be a risk of damage to the sealed package during such handling.

Moreover, it is only possible to dispense with a case/crate, if the cargo securing requirements in the container so permit. For example, a piece of machinery with a high center of gravity which is at risk of tipping over cannot be secured without destroying the sealed package. In this case, it is not possible to dispense with case packaging. Desiccants are placed inside the sealed package in order to maintain a relative humidity of 40%, so preventing corrosion damage. As explained in section 19.7, corrosion worsens rapidly at a relative humidity of 50%. This method only works if the film is absolutely impermeable to water vapor and there can be no exchange of air with the ambient air.

If a large amount of lumber is used to produce the sealed package, it releases water vapor due to its hygroscopicity; the water content of the lumber must be greatly reduced as even air dry lumber has an equilibrium moisture content of 70 - 75% at 20°C and a water content of 12 - 15% (see section 19.1). Large quantities of desiccant would have to be placed inside the package in such a case.

Figure 39: Sealed package for container transport;
Photo: Schieder [18]

12. Desiccants are commercially available which can be placed inside the container to absorb moisture. Since considerable quantities of water are present in the container (several 100 liters for cocoa) and, depending on their water content, hygroscopic cargoes frequently establish high equilibrium moisture contents in their environment, desiccants are not capable of absorbing sufficient moisture.
They will already be saturated before the actual problem time (unpacking of the container in the cold port of destination). The desiccants are not able to prevent the extremely high levels of moisture from "raining down" during unpacking. Figures 40 and 41 show desiccant bags placed in a container packed with a bagged cargo.

In Fig. 40, the desiccant bags have been placed at the bottom. However, since moist warm air rises upwards, desiccants must be placed, if they are to be used at all, in the upper third or better under the container ceiling so that they can be effective (see Fig. 41). Desiccant bags must also be placed in the upper third of a case inside a

sealed package.

Figure 40:
Desiccant bags at the bottom - wrong!
Photo: Stradt [53]

Figure 41:
Desiccant bags at the top - right!
Photo: Stradt [53]

Care must be taken to ensure that the bags do not come into contact with the packaged goods. Once saturated with moisture, they release it back into the surrounding environment, and contact with the package contents may result in corrosion. Such damage may even be more severe as desiccants are manufactured with salts, for example a mixture of bentonite with calcium chloride.

Fig. 42 shows sorption isotherms for the desiccants silica gel (type A = fine-pore silica gel; type B = large-pore silica gel) and activated alumina (Reimers [26]). Desiccant calculations are performed in accordance with DIN 55474.

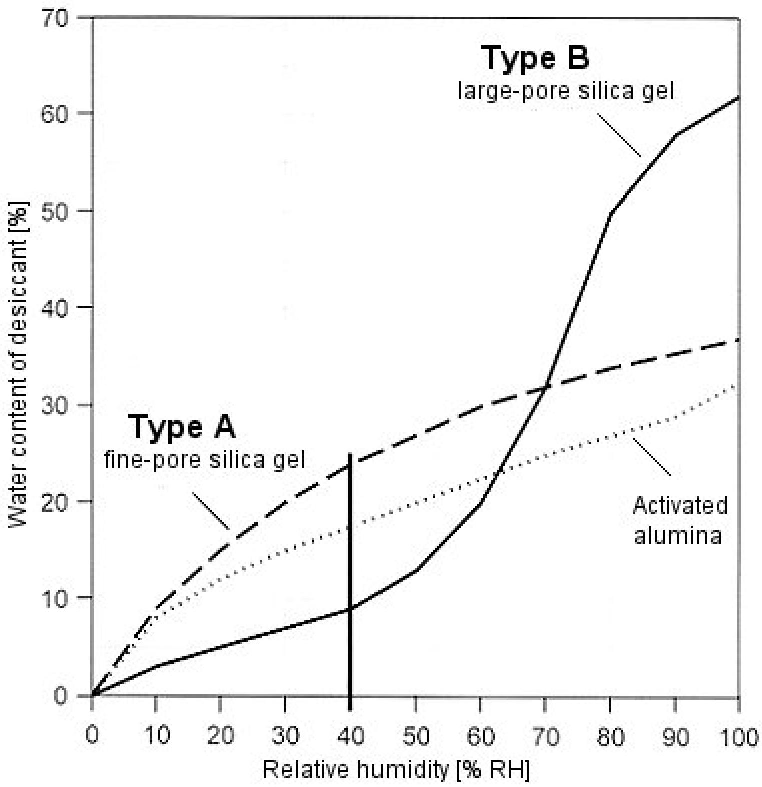


Figure 42: Adsorption isotherms for desiccants;
Reimers [26]

Grünewald made an estimate of the required quantities for a container transport operation on a simulated voyage from Australia to Europe (see Table 2 in Puls /25/).

Lumber and packaging material	Wooden pallets	Paperboard cartons
No.:	12 units	760 units
Weight:	200 kg	600 kg

Starting conditions in Melbourne, winter: 10°C, 75% relative humidity Intrinsic moisture content of packaging (at sorption equilibrium with 75% rel. humidity):	15 %	11 %
Container climate after 20 days (south of Dakar): air 30°C, cargo core 20°C		
Conclusion: The dew point of the air must not reach 20°C (corresponding to 54% rel. humidity) if sweat is to be avoided. The lumber and paperboard must thus be dried to the required new equilibrium moisture content: equilibrium moisture content at 50% rel. humidity:	10 %	8.5 %
Quantity of water to be removed during drying (difference between the 75% and 50% equilibrium moisture contents)	10 l	15 l
To sum up: In order to avoid sweat, water must be removed from the container air: according to Fig. 42 a desiccant will be required in a quantity of 100 kg (type A) or 165 kg (type B).	25 l (kg)	
If, as is often the case, the pallets consist of fresh cut lumber, the following intrinsic moisture contents must be expected: In which case, the following quantities must be adsorbed by the sorption agent:	20 % 20 l	11 % 15 l
Total:	35 l (kg)	
In this case, according to Fig. 42, desiccant is required in a quantity of 140 kg (type A) or 231 kg (type B).		

Table 2: Numerical overview of a desiccant requirement calculation for the transport of preserved fruit from Australia to Europe in a 20' container;
Grünewald in Puls [25]

Overall, in relation to the desiccant method, it is advisable to tailor the particular method to be used to the intended goods to be shipped because many different factors play a part, such as the sensitivity of the goods and the packaging, the intended transport route through different climatic regions, as well as logistical and cost factors.

13. Coffee, cocoa, rice, tea, tobacco and spices are particularly valuable goods, some originating from developing countries, which place particularly severe demands on container transport due to their hygroscopicity. The use of ventilated containers has made it possible to transport this class of goods with lower levels of loss than in a standard container. Fig. 43 shows a longitudinal section through a ventilated container, a 20' steel container, the interior of which is lined with perforated plywood.

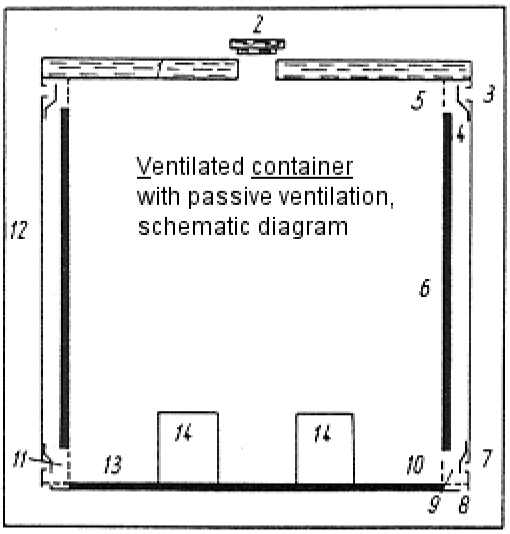


Figure 43: Ventilated container, suitable for bulk cargo (schematic);
Svenson [55]

The container has perforated battens at roof level (Figs. 44 to 47) and floor level (Figs. 48 to 50) which are coated with an anticondensation paint which is capable of absorbing a limited quantity of surface water, so delaying dripping of any water which may condense.

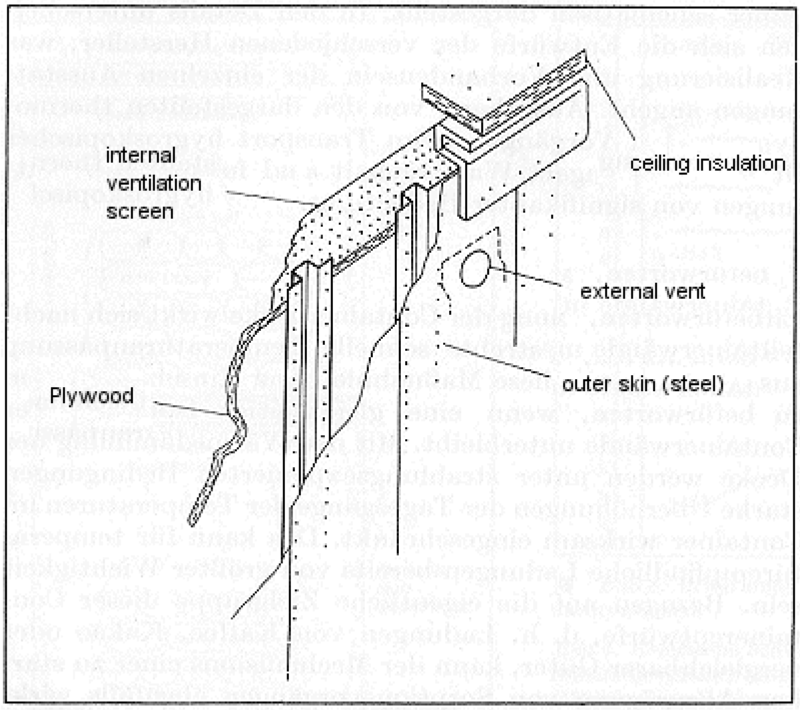


Figure 44: Structural details of a ventilated container;
Svenson [55]



Figures 45, 46 and 47 (from left to right) show the roof section of a ventilated container.
Photos: Schieder [18]

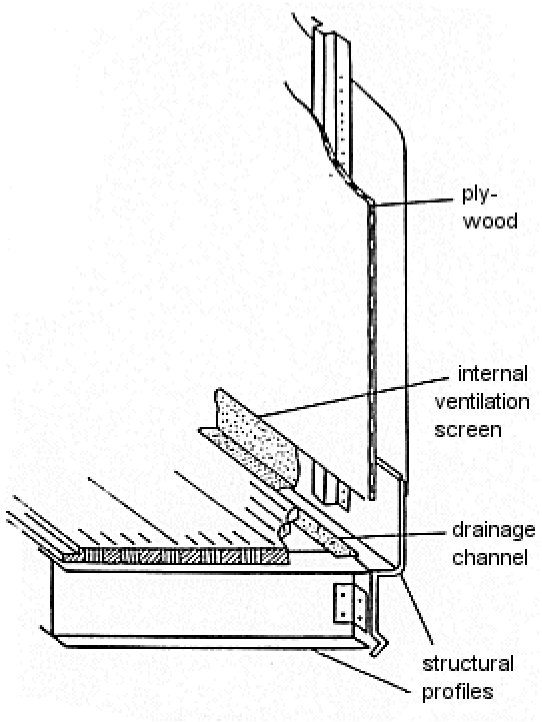


Figure 48: Structural details of a ventilated container; Svenson [55]

Figures 49 and 50 (from left to right) show the floor area of a ventilated container.
Photos: Schieder [18]

If, for example, a moist warm cargo (cocoa or coffee from Africa) is shipped to Germany in the winter, the temperature of the ambient air drops during the voyage. The relatively warmer air rises up inside the container and can escape through the perforated battens. The air escaping from the top is simultaneously replaced by cooler, relatively drier ambient air entering through the perforated battens in the container floor.

This upward-moving air stream can be assisted by hold ventilation. It is therefore generally advisable to stow the containers below deck.

Fresh air is supplied via the floor area of the hatch and extracted again in the upper area. In this way, condensation in the container roof area may largely be avoided: formation of a stationary, moist, warm layer of air immediately below the ceiling, as is formed in a standard container (see Fig. 51a), is prevented by air turbulence under the container ceiling caused by the rising air heated by the wall surfaces (Fig. 51b). Breaking down the stable stratification under the container ceiling thus limits the progressive formation of sweat.

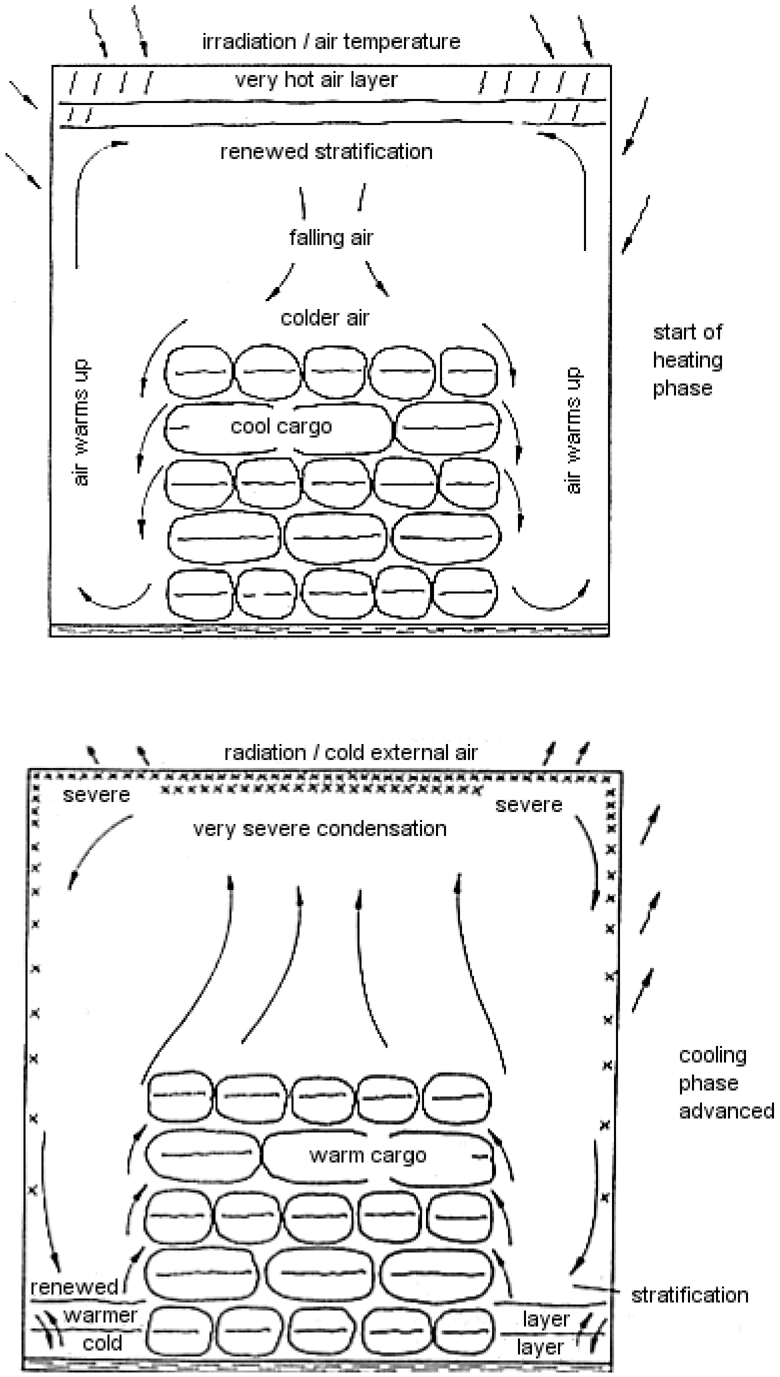
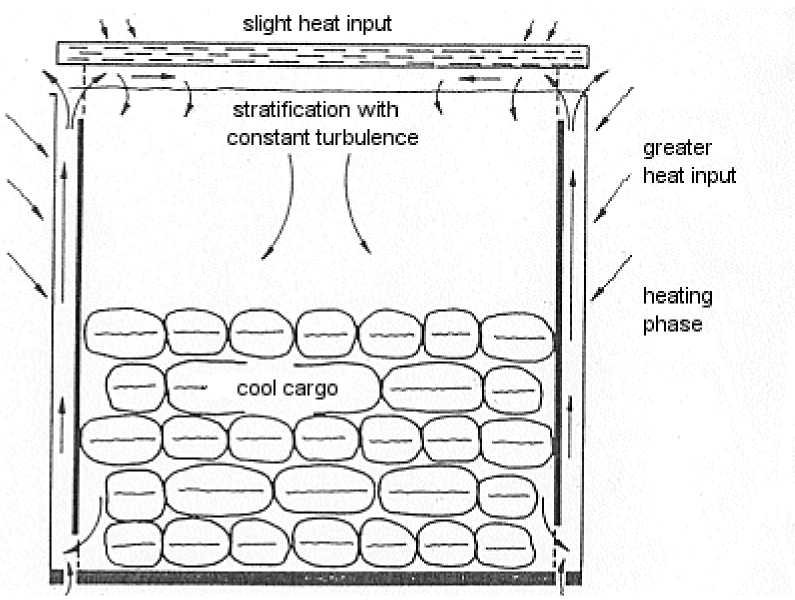


Figure 51a: Heating and cooling in a standard container;
Svenson [55]



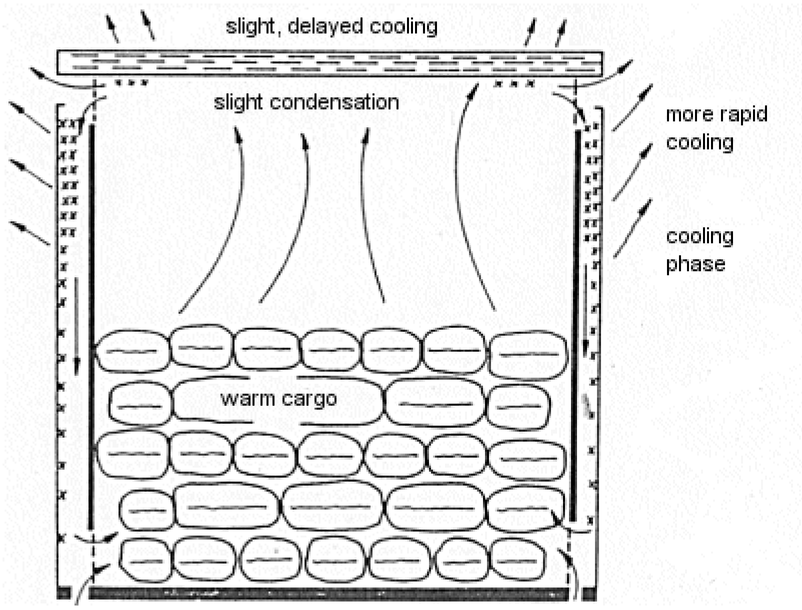


Figure 51b: Heating and cooling in a ventilated container;
Svenson [55]

10.4 Interrelationships between cargo type, container type and stowage space

In the past few years, considerable successes have been achieved in the container transport system in the field of cargo care, in particular by improving the fitness for container transport of the goods, especially with regard to transport of goods in standard containers.

10.4.1 Selection of suitable container type

As a result of development of the refrigerated container, the transport of highly perishable goods on flatracks in actively ventilated holds (e.g. on ro/ro ships), the naturally ventilated container and open containers, a wide range of options exists from which the ideal solution may be selected for each particular cargo (Fig. 52).

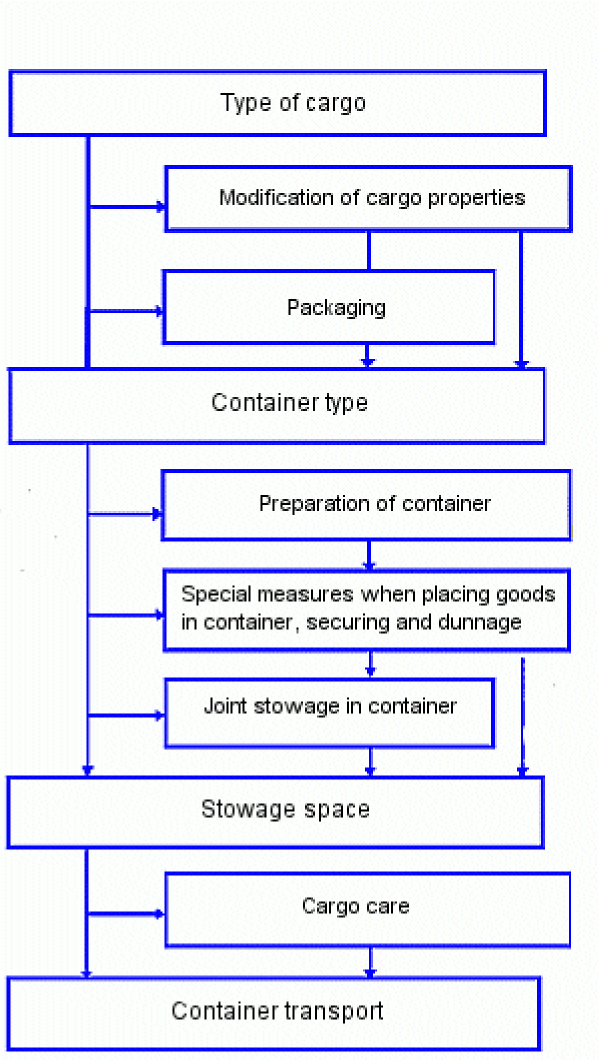


Figure 52: Adapting a cargo type to container transport conditions;
U. Scharnow [42]

Each of the four possible measures:

- Modification of cargo properties and/or its packaging
- Selection of suitable container type
- Allocation of a suitable stowage space
- Performing the necessary cargo care measures

has its limitations and, for many goods, cannot alone prevent transport losses or requires considerable expenditure, so calling cost-effectiveness into question. Furthermore, each of the four measures is also subject to certain restrictions.

As a rule, however, an optimum can only be achieved when several measures are used at the same time in the interests of maintaining cargo quality. How a cargo should in principle be allocated to the suitable container is shown in the flowchart in Fig. 53, which shows only a few selected decisions just to give an idea of the problems involved.

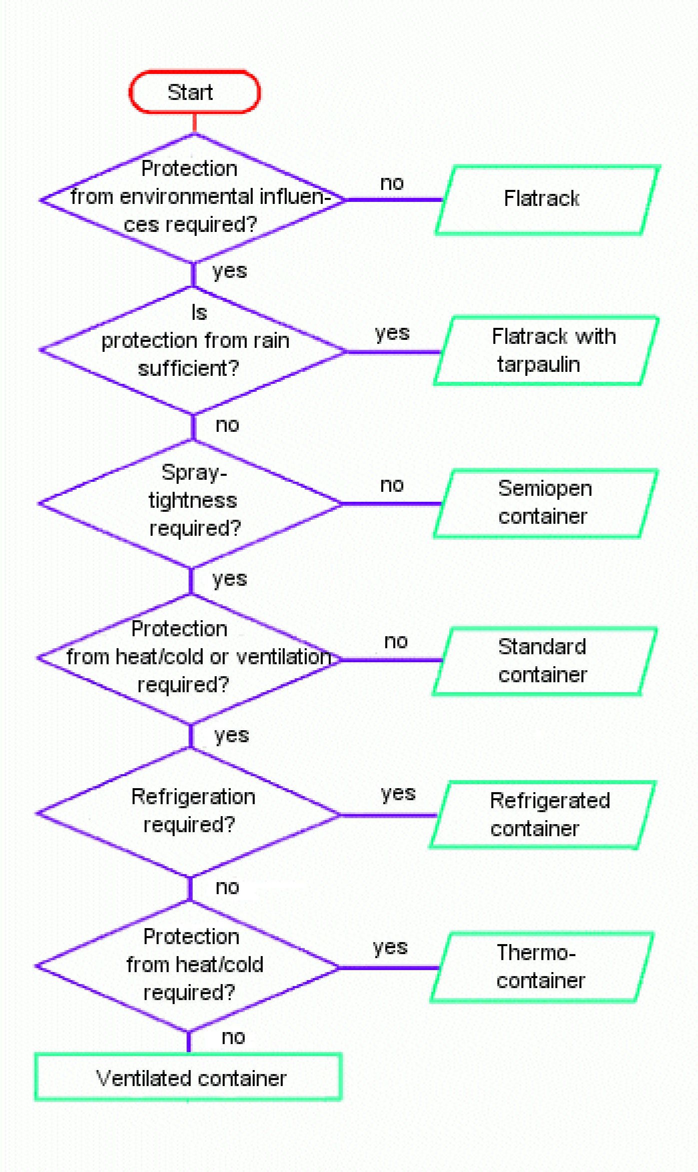


Figure 53: Selection of suitable container type; U. Scharnow [42]

It is possible in principle to make all goods suitable for container transport. To what extent quality degradation can be minimized will depend on how the issues of "fitness for container transport" and of cargo care are managed during transport.

10.4.2 Stowage space requirements on a container ship

A question which is at present still open to debate is that of allocating the stowage space on board ship which is optimum for the particular cargo. Present practice is to allocate stowage space with regard to optimum packing and unpacking technology, the only restrictions applying in the case of hazardous goods of the IMDG code and of refrigerated containers, which naturally have to be allocated the spaces provided for them.

Other requirements relating to maintaining cargo quality, such as radiation protection, shipment below deck, protection from heat sources etc., are given little consideration. Opinions will have to change if goods of vegetable origin are to be transported by container in any considerable quantity. The current practice of allocating containers to stowage spaces must of course be accepted for the majority of industrial goods, but is inadequate for sensitive goods.

Fig. 54 shows the different stowage spaces available on board a container ship. The significant difference with regard to cryptoclimate depends on whether the containers are stacked below deck or on the upper deck. None of the containers shipped below deck are exposed to radiant input and they are all protected during the voyage from spray and rainwater.

The daily variation in temperature of the ambient air is considerably more stable than on deck. A disadvantage is the low level of air movement, since the hold ventilation stream has little effect on a closed standard container, though a perceptible air exchange does occur in passively (naturally) ventilated containers. On the other hand, however, open containers packed with moisture-sensitive goods may also be transported below deck, such as citrus fruits on flatracks in the ventilated holds of
ro/ro ships.

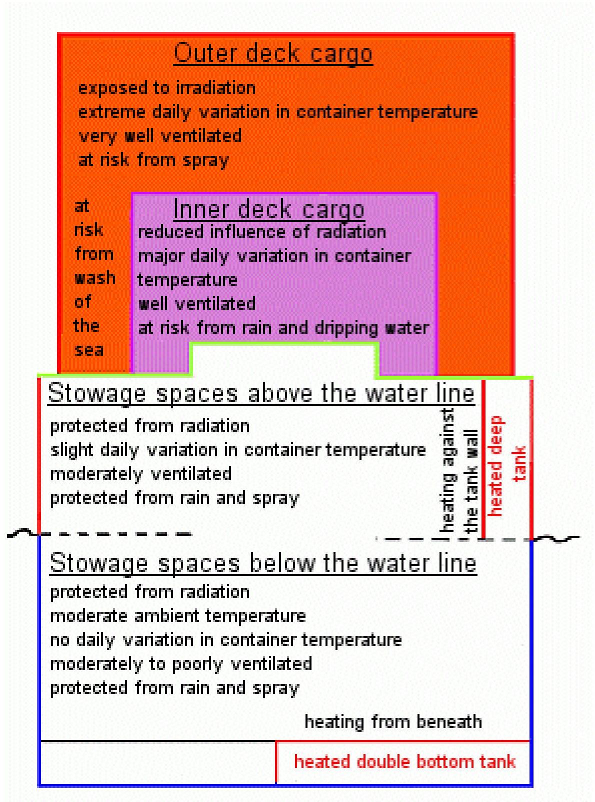


Figure 54: Stowage spaces on a container ship; U. Scharnow [42]

Containers which are transported on deck are exposed to solar radiation. A high degree of daily variation in temperature in the container will occur, resulting in more severe formation of container sweat during night-time cooling, this also being greater than in the hold.
The risks posed by spray and rainwater are also significant. Door and roof leaks are probably the main causes of damage. Only in a few cases will these deficiencies be detected in a packed container.

Packing should consequently be commensurate with the value of the cargo and its sensitivity to moisture.

For instance, containers packed with batteries or high-quality microelectronics or with musical instruments should be stowed in the hold.
The same applies to hygroscopic goods, such as malt or tea. On the other hand, glass or porcelain goods, machine parts etc. suffer less damage when shipped on deck.

On deck too, a distinction may be drawn between the outer and inner layers of containers, the latter being less severely exposed to radiation and spray.

However, even in the hold the individual stowage spaces exhibit different travel temperatures. For instance, a container standing on a heated double bottom cell or a bulkhead to a heavy oil tank will be subject to considerable heating.

Even if modern data-processing were theoretically to allow individual container slot allocation, the operational requirements of the shipping companies and terminal operators would not allow such specially tailored stowage.

11 Factors determining goods storage climate conditions

11.1 Classification of goods by water content classes

The transport requirements of goods with regard to storage climate conditions in the container are largely determined by their water content and their resulting interaction with the humidity and temperature conditions of the ambient medium. The water content of a product is the percentage of its total mass which is constituted by water. Goods may therefore be classified by the following water content classes:

WCC = Water content classes

0 - Water content class 0 (WCC 0)
Products containing no water, e.g. glass, porcelain, ceramic fittings, metals, plastics.

1 - Water content class 1 (WCC 1)
Products containing only a little water (water content > 0 to ≤ 1.5%), e.g. crystalline and pulverulent products (sugar, salt, fertilizers, citrus powder); their adsorption isotherms are characterized by discontinuities.

2 - Water content class 2 (WCC 2)
Goods with a low water content (WC > 1.5 - ≤ 30%), e.g. goods from which water has been removed by natural or artificial drying, thereby extending storage life, such as most foodstuffs and semiluxury items, also raw materials of animal origin, natural fibers, coal, lumber, paper; their adsorption isotherms form a continuous, generally S-shaped, curve.

3 - Water content class 3 (WCC 3)
Goods with a high water content (WC > 30%), including fruit, vegetables, meat and fish, with a water content of > 90%, which have a tendency to release water vapor (water vapor release) into the storage atmosphere. This group also includes goods, such as rafted wood or wet-salted hides (which under normal conditions belong to WCC 2).

11.2 Biotic activity of goods

The biotic activity of a product plays an important role in its classification with regard to container storage climate conditions. Most foodstuffs and animal feedstuffs and some industrial products are of an organic nature. They are in constant active or passive interaction with the environment.

Goods may be classified by the following activity classes on the basis of their particular biological properties:

0 - no biotic activity (BA 0)
Nonliving goods, goods exhibiting passive behavior (porcelain, plastics, steel and chemical products)

1 - Goods displaying 1st order biotic activity (BA 1)
Living organisms with fully maintained intrinsic metabolism, in which anabolic metabolic processes predominate, e.g. livestock (domestic and zoo animals) and poultry. Anabolic and catabolic metabolic processes must be kept at least in equilibrium by appropriate feeding and care.

2 - Goods displaying 2nd order biotic activity (BA 2)
Living organisms, such as fruit (bananas, citrus fruits, pomaceous fruit), vegetables (tomatoes, sweet peppers, potatoes, onions), grains, legumes, oil-bearing seeds/fruits, in which respiration processes predominate, because their supply of new nutrients has been cut off by separation from the parent plant.

3 - Goods displaying 3rd order biotic activity (BA 3)
Goods in which respiration processes are suspended, but in which biochemical, microbial and other decomposition processes still proceed, such as meat, fish, processed grain products, dried fruits, spices, cocoa and coffee beans, tea, tobacco, expellers, fish meal, crystalline goods (sugar, salt, fertilizing salts). Such goods are not provided with hermetically sealed packaging.

4 - Goods displaying 4th order biotic activity (BA 4)
Goods in which biochemical and microbial processes have stopped and which are isolated from the external environment, e.g. sterilized and pasteurized goods in hermetically sealed packaging (preserved foods, beverages).

11.3 Requirements and interrelationships of goods with regard to storage climate

Assignment of goods to a particular class of storage climate conditions (SC) is carried out on the basis of the requirements they place upon their storage atmosphere. Depending on the classification of the product, different parameters have to be taken into account with regard to the risk factors temperature, humidity/moisture and ventilation to prevent a reduction in product quality.

The following definitions apply:

- Goods which require particular temperature conditions:
  Goods which, during storage, must not exceed a maximum temperature or fall below a minimum temperature and/or which are sensitive to temperature variations

- Goods which require particular humidity/moisture conditions:
  These include goods which make particular demands of the atmospheric water vapor content and in general interact with the water vapor in the air (hygroscopic goods). With such goods, it is necessary to ensure that the relative humidity in the container complies with certain upper or lower limits.

- Goods which require particular ventilation conditions:
  These include goods which have particular requirements with regard to the composition of the atmosphere, e.g. respiring goods (fruit, vegetables), which require the supply of oxygen and removal of carbon dioxide and ethylene. Particular ventilation conditions may also reduce the risk of sweat water formation where hygroscopic goods are concerned.

These three different classes of conditions may occur individually or in combination. These definitions give rise to the following groups. The particular classification of a product depends, among other things, on its water content and its biotic activity.

SC 0 Goods not subject to any conditions, which place no requirements on storage climate conditions:
Goods which contain no water (WCC 0) and do not absorb any water vapor when stored in an outdoor atmosphere and which do not have any particular storage temperature requirements belong to this group. Nor do they exude harmful substances. Examples are industrial ceramics, ceramic fittings, porcelain.

This group also includes goods in hermetic packaging, i.e. packaging impermeable to water vapor, irrespective of whether the goods themselves are hygroscopic, e.g. goods in cans or barrels.

SC I - Goods which require particular ventilation conditions:
Goods, which contain no water (WCC 0) and also do not interact hygroscopically with their surroundings and which do not have any particular storage temperature requirements, require particular ventilation conditions in order to eliminate contaminants which are detrimental to health and form explosive mixtures in conjunction with air. Examples of these are motor vehicles, the exhaust gases from which must be removed during ro/ro operation.

Hazardous materials which generate harmful substances which have to be removed by ventilation should also be classified in this group.

SC II - Goods which require particular temperature conditions:
These goods may suffer damage if the temperature exceeds or falls below certain limit values. They include goods which contain no water (WCC 0) or only a little water (WCC 1), for example goods with thermoplastic properties, such as resins, waxes and bitumen, which become soft and deform if the upper temperature limit is exceeded; if they then enter a lower temperature zone, they may become jammed.

SC III - Goods which require particular temperature and ventilation conditions:
This group includes goods whose requirements constitute a combination of groups SC I and SC II, i.e. they are temperature-sensitive and require the removal of harmful substances; examples are hazardous materials, gas-releasing products and chemicals.

SC IV - Goods which require particular humidity/moisture and possibly ventilation conditions:
These include goods which contain no water (WCC 0) and which are damaged by moisture, for example all goods at risk of corrosion, such as metals, machines, instruments. Industrial glass may be damaged by "dulling" due to the action of humidity/moisture.

If the goods are container dry, ventilation is unnecessary. Ventilation is necessary if moisture has to be removed.

Hygroscopic crystalline goods which deliquesce through water vapor adsorption and can then cake due to water vapor release, such as sugar, salts, fertilizers, also belong to this group.

SC V - Goods which require particular humidity/moisture and ventilation conditions:
Goods which react sensitively to moisture and in so doing generate harmful substances, such as hazardous materials and goods which may generate flammable gases on contact with water.

SC VI - Goods which require particular temperature, humidity/moisture and possibly ventilation conditions:
Hygroscopic goods with low water content (WCC 2), which constantly interact with the temperature and humidity/moisture conditions of the ambient medium and display 3rd or 2nd order biotic activity, are damaged by moisture on the on one hand (mold, rot, mildew stains, fermentation, self-heating or by desiccation (solidification, jamming/caking, fragmentation, drying-out) on the other. They include most foodstuffs, semiluxury items and animal feed, and also packaging materials, natural fibers, lumber.

If they are container dry, they do not require ventilation. To achieve the necessary temperature and humidity parameters, ventilation may be required. Since this is impossible in standard containers, damage will have to be expected from the outset with cargo which is not container dry.

SC VII - Goods which require particular temperature, humidity/moisture and ventilation conditions:

In the case of goods with a high water content (WCC 2) and 2nd order biotic activity (BA 2), such as fruit and vegetables, in which respiration processes predominate, ventilation has not only to ensure that temperature and humidity requirements are met but also gas exchange, i.e. removal of carbon dioxide and ethylene and supply of oxygen, as performed in refrigerated containers.

SC VIII - Goods which require a controlled atmosphere (CA containers):
A decisive improvement in storage conditions in the container is achieved by generating a controlled atmosphere (CA = Controlled Atmosphere. As well as lowering the temperature, the oxygen content is reduced from 21% to 3 - 5% and the carbon dioxide content is raised from 0.03% (CO_2 content in normal atmosphere) to 5 - 25%, thereby reducing respiration in fruits and extending the shelf life of fruit and vegetables in comparison to conventional chilling. With certain goods, a controlled supply of moisture may be necessary. This technology is not yet fully developed.

11.4 Container transport of products

11.4.1 Goods of water content class 0, not subject to any conditions 0 (WCC 0)

11.4.2 Goods of water content classes 1 - 3 (WCC 1 - 3)

Internationally, a large number of special containers has been developed; this makes it difficult, however, to build up container lines which are capable, for example, of carrying predominantly industrial products on the outward leg and agricultural products on the homeward journey. This problem is referred to as a trade imbalance.
Unbroken transport chains require an optimum compromise to be achieved between the transport requirements placed on the container type by a cargo, on the one hand, and the adaptation of the cargo to a small variety of universally applicable container types, on the other. However, investigations into losses have shown that cargoes are not always fit for container transport when packed into the container. "Fit for container transport" means the demands a cargo places on the storage climate conditions in the container.

Moisture damage caused by condensation water has been noted principally in hygroscopic goods, on the container walls or on the goods themselves, for example in jute bales traveling from Chittagong to Bremen, whilst wetting damage has been noted on Indian craft items from Bombay, also in green coffee beans, raw cocoa, millet, dried fruit, sago, pepper, milk powder, fleeces, textiles and goods at risk of corrosion, such as preserved foods, steel and steel products.

The transport requirements of goods with regard to storage climate conditions in the container are largely determined by their water content and their resulting interaction with the humidity and temperature conditions of the ambient medium as well as by their biotic activity, these being the determining factors in allocation to the most suitable container type.
The following distinctions are drawn:

- Water content classes (WCC)
- Biotic activity (BA) classes
- Requirements placed by a cargo on storage climate conditions (SC)

From the water content class, together with the biotic activity of the cargo, it is possible to deduce the different storage climate conditions requirements which are of relevance to the question of container transport of the products and the selection of the container type.

Product groups - Criteria	**Ceramic products (industrial ceramics, ceramic fittings**	**Crystalline goods (sugar, salt, fertilizer)**	**Dried fruit, spices**	**Shell fruit, green coffee beans**	**Meat, fish**	**Fruit, vegetables**	**Living animals**
Pack-aging	unpackaged, plastic film	double-layered bags (outside jute, inside plastic)	jute bags, cartons	jute bags	cartons	jointed boxes, car-tons	-
Water content class (WCC)	WCC 0	WCC 1	WCC 2	WCC 2	WCC 3	WCC 3	WCC 3
Biotic activity (BA)	BA 0	BA 3	BA 3	BA 2	BA 3	BA 2	BA 1
Storage climate conditions (SC)	not subj. to any conditions SC 0	temperature, humidity/moisture and possibly ventilation conditions SC VI			SC VI	SC VII, SC VIII	SC VII
Container type	flatrack (open container)	standard container, bulk container	standard container	ventilated container	low temp. refrig. container	refrigerated container with	livestock container

						fresh air supply, CA container	
Restric-tions	protection from rain and spray desirable	goods and packaging must be container dry: compliance with lower limits set for water content of goods, packaging and pallets			compliance with cold chain	Comply with cold chain	Protect from atmos-pheric factors (sensitive to drafts)
Stowage space	on deck, unprotected or with tarpaulin	may be disadvantageous on deck	below deck where possible, protect from spray and heat sources		on and below deck		mostly on deck
				ventilate intensively below deck			

Table 3: Allocation of some product groups to container types

Table 3 illustrates the allocation of some typical examples of products or product groups to container types, the following criteria being taken into account: packaging, water content class, biotic activity, storage climate conditions, container type, restrictions and stowage space.

11.4.1 Goods of water content class 0, not subject to any conditions (WCC 0)

Goods of water content class 0 do not generally place any particular requirements on storage climate conditions, and are also biologically inactive (BA 0).

The following distinctions may be drawn:

- Goods which do not require any protection from environmental influences and may therefore be transported on deck without protection. Examples are goods on open containers, such as flatracks, open-top containers and/or open-sided containers, for example construction plant, structural steel, industrial ceramics, and also goods in hermetic packaging, i.e. packaging impermeable to water vapor, e.g. barrels, cans etc.
- Goods which require protection from rain or spray and solar radiation and are therefore transported on deck with protection, e.g. flatracks with tarpaulins or in containers with roofs ("semiopen containers"), such as steel products (risk of corrosion) or rubber products (aging processes).

11.4.2 Goods of water content classes 1 - 3 (WCC 1 - 3)

All the other goods of water content classes 1 - 3 (WCC 1 - 3) place particular requirements on storage climate with regard to temperature humidity/moisture and ventilation.

Goods with a low water content (< 1.5%) (WCC 1) and low, 3rd order biotic activity (BA 3)

These goods undergo only biochemical and microbial degradation processes and include hygroscopic crystalline goods, such as sugar, salt, fertilizer (potash) and chemicals which reach their flow moisture point at φ > 70%, resulting in an abrupt change in the adsorption isotherms; in the event of further water vapor adsorption, they deliquesce, leading in the case of sugar to syrup formation (see Fig. 5 in Section. 10.2.7). They require particular humidity/moisture and possibly ventilation conditions (SC IV).

Where temperature differences are too severe, water vapor release may occur, which may result in lump formation (agglomeration) and often in complete hardening; transporting the containers on deck may therefore be disadvantageous. If the goods are container dry, they do not require any ventilation; ventilation then only becomes necessary if moisture has to be removed, which is impossible with standard and bulk containers; however, transport in standard and bulk containers may be possible if additives are incorporated (to prevent lump formation). It may be necessary to close any fan outlets present.

In practice, if no additives are incorporated, moisture and agglomeration damage occur repeatedly in containers.

Goods with a low water content (> 1.5 to ≤ 30%) (WCC 2) and low, 3rd order biotic activity (BA 3)

These are typical hygroscopic goods with distinctive sorption behavior (S-shaped adsorption isotherms), which include many foodstuffs, semiluxury items and animal feedstuffs, such as dried fruit, spices, tea, tobacco. They are goods in which respiration processes are suspended, but in which biochemical, microbial and other decomposition

processes still proceed. They must not suffer any moisture damage (mold, rot, fermentation, postfermentation) or desiccation damage (fragmentation, drying-out). This group also includes packaging materials (lumber, cardboard, paperboard) and pallet lumber, except that these are generally biologically inactive. These goods require ventilation (SC VI), which is impossible in standard containers. However, such goods may be transported without damage in standard containers if the water content of goods, packaging and pallets is kept so low that a correspondingly low equilibrium moisture content < 75% (mold growth threshold) is established, which corresponds to a temperature/dew point difference of > 6°C: the greater this difference, the lower the risk of sweat water upon cooling in the container (see Section 10.2.8). The goods should therefore be "container dry".

Notes on damage prevention (see Section 10.3.7)

Moisture damage caused to hygroscopic goods in standard containers by the formation of condensation water may be reduced by:

- Reducing the water content by pre-drying of goods, packaging, pallets and container flooring
- Laying paper dunnage
- Suspending a plastic sheet with condensation reservoir
- Using non-hygroscopic packaging materials, e.g. shrink film wrappings, aluminum foil in plywood chests, e.g. for tea, film lining impervious to water vapor for example for dried milk and sugar bags
- Suspending a nonwoven fabric, which is attached beneath the container ceiling
- So as to be able to transport bulk cargo in a standard container, a liner bag made from a strong woven plastic fabric can be suspended in the container. Since container bulk cargo is very often hygroscopic, the liner bag is also available combined with an integral nonwoven fabric.
- So-called sealed packages combined with the desiccant method for container transport of high quality technical goods
- Using ventilated containers for particularly sensitive hygroscopic goods, such as coffee, cocoa, rice, spices

Goods with a low water content (> 1.5 to ≤ 30%) (WCC 2) and 2nd order biotic activity (BA 2)

Due to their distinctive sorption behavior and high biotic activity (respiration and degradation processes), these hygroscopic goods separated from their parent plant require particular temperature, humidity/moisture and ventilation conditions (SC VI). Ventilated containers (known as "coffee containers") are appropriate, at the very least.

Natural ventilation takes the form, as is known, of the inlet of air through openings in the sides of the lower side rails; the air is heated by the cargo in the container, rises and may leave the container again through slots in the upper side rail.

This warm, moist air is able to escape, so that even the container ceiling dries off and/or no sweat develops (see Section 10.3.7).

If stowed in the hold, the ventilated container requires more intensive hold ventilation or a stowage space where this ventilation may reach it to the necessary degree.

For product groups with a tendency to self-heating, such as shell fruit, oil-bearing seeds/fruits, the "coffee container" is preferable to the standard container.

Particularly problematic with regard to containerization are cocoa beans (vapor damage, mold damage, total loss of aroma) and pepper (release of large quantities of water vapor, self-heating) and these goods must accordingly never be transported in a bulk container.

Goods with a high water content (> 30% to ≤ 90%) (WCC 3) and high 2nd order biotic activity (BA 2)

These include highly perishable goods with a high water content, such as bananas, pineapple, citrus fruit, pomaceous and stone fruit, berry fruit, vegetables, potatoes and onions. Since these are living organisms separated from the parent plant, the respiration processes have to be specifically controlled (e.g. "dormancy temperatures"; particular temperature, humidity/moisture and ventilation conditions (SC VII) are therefore required, as is intensive ventilation. Refrigerated containers with a fresh air supply, i.e. thermally insulated refrigerated containers with a fully air-conditioned atmosphere, or CA containers (controlled atmosphere containers SC VIII) are necessary.

Meat and fish also belong to this group, but their biotic activity is only 3rd order (BA 3), so meaning that only particular temperature and humidity/moisture conditions (SC VI) are necessary and they are generally transported in low-temperature refrigerated containers.

Goods with a high water content (> 90%) (WCC 3) and 1st order biotic activity (BA 1)

These are living organisms with fully maintained intrinsic metabolism, in which anabolic metabolic processes predominate: examples are livestock (animals for breeding and for slaughter), zoo animals and poultry. Loss-free transport in livestock containers, e.g. of horses, pigs, zoo animals, must be ensured by the provision of food, water and care.

Summary and future prospects

The above statements reveal that different goods display a range of sensitivities to climatic stresses, depending on their water content and biotic activity, and that containers range accordingly from the flatrack for goods not subject to any conditions, through standard containers, ventilated containers, refrigerated containers with full air conditioning or CA containers with a controlled atmosphere to livestock containers for living animals, which latter place the most stringent requirements on storage climate conditions (see Table 3, Allocation of some product groups to container types).

Product groups - Criteria	**Ceramic products (industrial ceramics, ceramic fittings**	**Crystalline goods (sugar, salt, fertilizer)**	**Dried fruit, spices**	**Shell fruit, green coffee beans**	**Meat, fish**	**Fruit, vegetables**	**Living animals**
Pack-aging	unpackaged, plastic film	double-layered bags (outside jute, inside plastic)	jute bags, cartons	jute bags	cartons	jointed boxes, car-tons	-
Water content class (WCC)	WCC 0	WCC 1	WCC 2	WCC 2	WCC 3	WCC 3	WCC 3
Biotic activity (BA)	BA 0	BA 3	BA 3	BA 2	BA 3	BA 2	BA 1
Storage climate conditions (SC)	not subj. to any conditions SC 0	temperature, humidity/moisture and possibly ventilation conditions SC VI			SC VI	SC VII, SC VIII	SC VII
Container type	flatrack (open container)	standard container, bulk container	standard container	ventilated container	low temp. refrig. container	refrigerated container with fresh air supply, CA container	livestock container
Restric-tions	protection from rain and spray desirable	goods and packaging must be container dry: compliance with lower limits set for water content of goods, packaging and pallets			compliance with cold chain	Comply with cold chain	Protect from atmos-pheric factors (sensitive to drafts)
Stowage space	on deck, unprotected or with tarpaulin	may be disadvantageous on deck	below deck where possible, protect from spray and heat sources		on and below deck		mostly on deck
				ventilate intensively below deck			

Since several factors determine the suitability of a product for a specific container type, and the stowage space on the ship, the duration of the voyage and the climatic regions to be travelled through depending on the season are also significant, the choice of container type, the quality of the packaging and the pretreatment of the cargo itself require thorough consideration, if transport damage is to be avoided.

On the TIS Cargo information pages (http:www.tis-gdv.de), the fitness for container transport of every type of product is assessed by the method described above, which has been proven to provide valuable guidelines in particular for transport professionals.

12 Transport properties of products

12.1 Definitions

→ 12.2 Compatibility characteristics

12.1 Definitions

Most changes occurring during transport, handling and storage operations are unwanted and considered damage. Only a few changes, such as postfermentation of tobacco, tea, green coffee beans and raw cocoa or ripening of cheese, are desirable changes, and even these may turn into unwanted changes if the processes are not properly controlled.

- Cargo properties are understood to be the typical properties of a cargo, describing its characteristic features and characterizing its specific functions, its utility value and its quality, i.e. a cargo is described by a large number of properties.

- Transport properties merely cover the properties of a cargo which need to be taken into account so as to ensure loss-free transport, including handling and storage operations.

- In practice, a distinction is drawn on the basis of structure between individual packages and loose goods (see Fig. 55). Loose goods consist either of solid particles (dry bulk cargo) or liquids (liquid bulk cargo), from which the appropriate container types (bulk container, tank container) may be deduced.

- Individual packages are known as general cargo, which may be divided, depending on atmosphere requirements (natural, partially air-conditioned or temperature-controlled atmosphere), into general cargo, general cargo requiring ventilation and refrigerated cargo, which place corresponding requirements on containers (general purpose container, ventilated container, refrigerated container), or indeed into further sub-categories (see Figs. 55, 56).

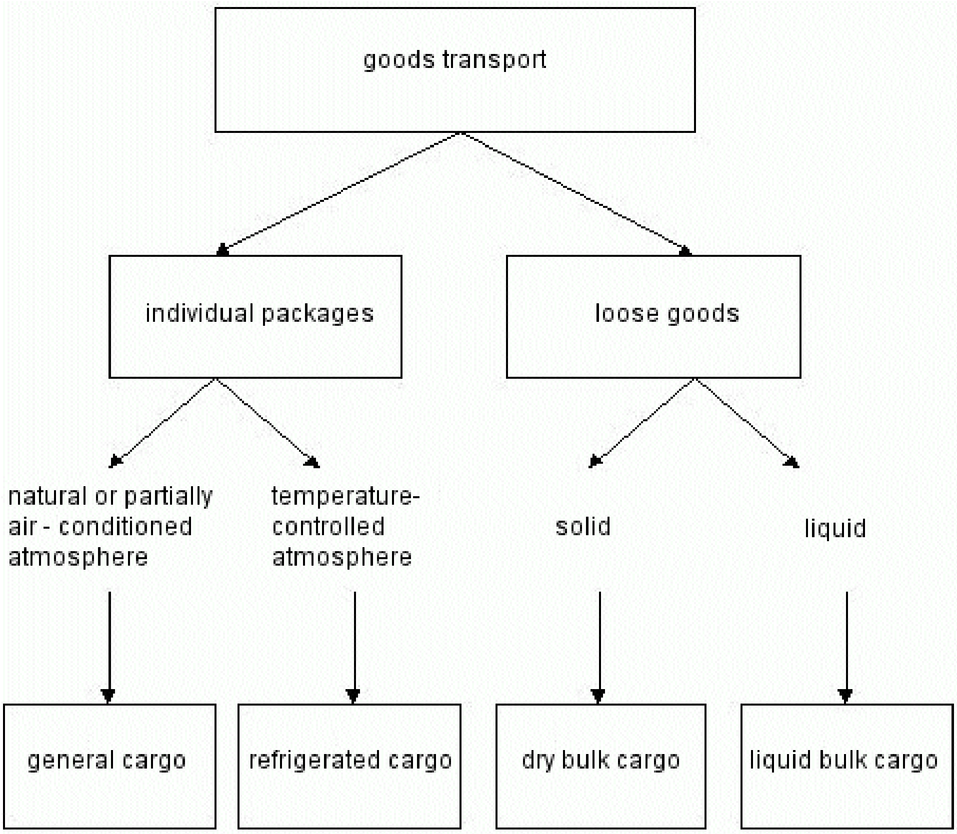


Figure 55: Classification of goods to be transported

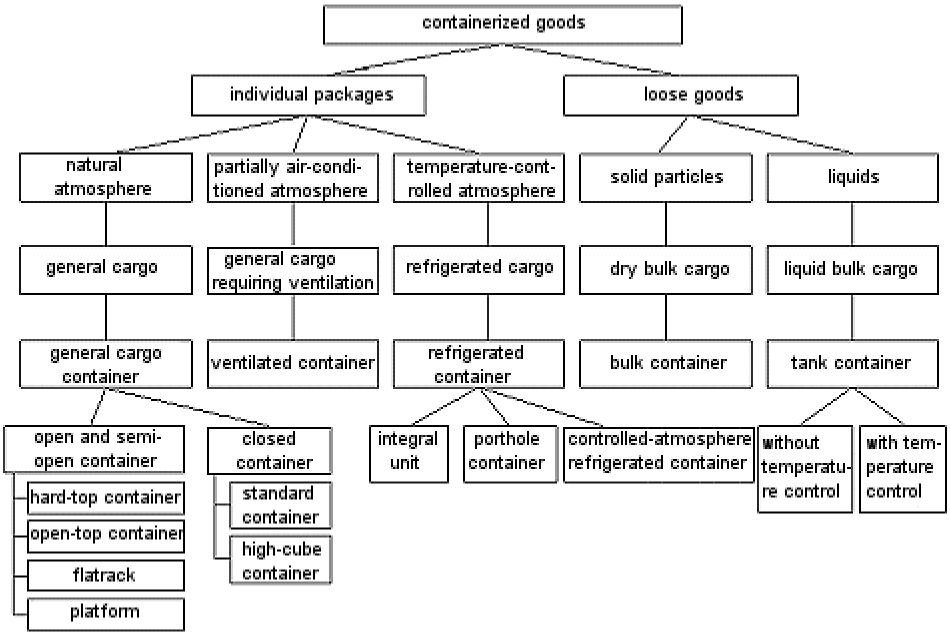


Figure 56:
Flowchart of container types according to requirements of goods to be transported

12.2 Compatibility characteristics

If goods are to be stowed together when packing a container, the interrelationships between the transport properties of products must be taken into account, since disregarding them may result in quality degradation and damage. Goods may react with one another and possibly with their environment. They may be classified as follows, depending on their degree of active or passive reaction (see Fig. 57):

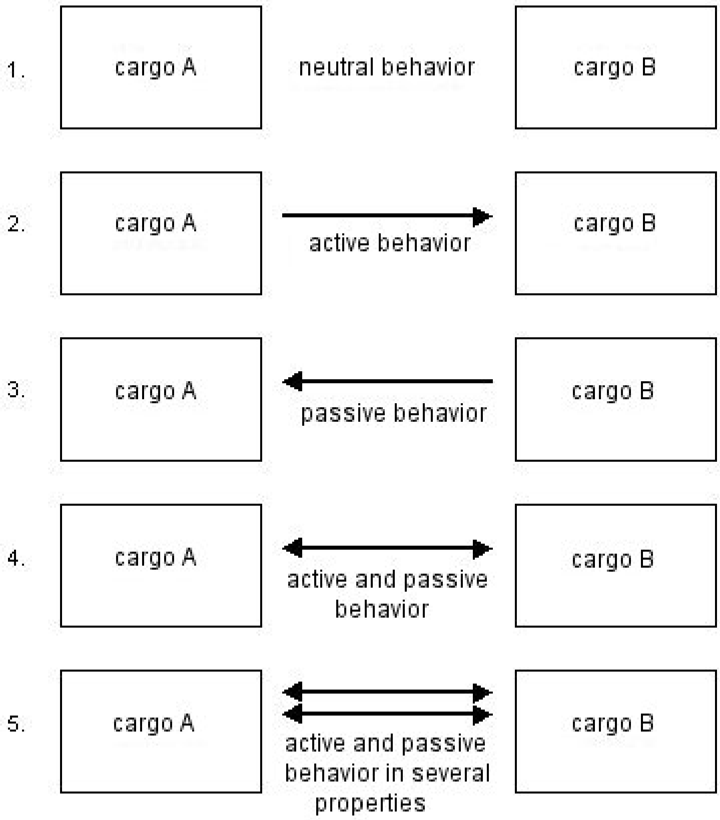


Figure 57: Compatibility relationships of goods

1. Goods displaying neutral behavior:

   Mutually compatible goods are those which do not impair or damage one another when stored together in a warehouse or in a container during transport, i.e. display neutral behavior. These goods present no containerization problems, their neutral behavior meaning that they place no special requirements on container type nor on container stowage space; examples are ceramic fittings, roof tiles, construction plant, rough structural steel, boats etc. (WCC 0), which do not affect one another with regard to humidity/moisture, odor or contamination.
   However, it must be remembered that the wooden crates or pallets (WCC 2) are moisture-sensitive and may therefore suffer a loss of stability. Sodden pallets may lose up to 50% of their strength. For instance, pallets carrying roof tiles which had stood for a long time in the open air became rotten and broken and clearly should have been classified as goods displaying passive behavior. This should be taken into account when considering neutral behavior.

2. Goods displaying active behavior:

   Goods, one of whose particular properties has an active effect on other goods or on the environment, display active behavior. As a rule, the active behavior of a cargo results in unwanted changes, for instance it may cause quality degradation/damage in other goods. This means that a cargo displaying active behavior can only be stowed together with goods which do not deteriorate in quality or become damaged due to this active behavior, for example asafetida, a gum-resin, is known by its penetrating odor, which is difficult to remove and therefore must not be packed in a container together with odor-sensitive goods, but is itself not odor-sensitive.

3. Goods displaying passive behavior:

   Goods which are sensitive to a particular property of other goods or of the environment, display passive behavior. Changes which are often irreversible and lead to quality degradation/losses are caused to the cargo by active behavior external to it, i.e. of other goods or the environment.
   For instance, window glass, which does not contain any water (WCC 0) and therefore does not release any water vapor, could be dulled by a damp environment if stored in the open air for a relatively long time at the port of loading.

4. Goods displaying active and passive behavior:

   Goods, one of whose particular properties displays both active behavior and passive behavior; they are capable both of causing quality degradation/damage to other goods and of undergoing quality degradation/damage as a result of other goods. An example is gum arabic, which on the one hand causes contamination by exuding sticky substances and on the other hand is sensitive to contamination in the same manner as foodstuffs.

5. Goods displaying active and passive behavior in more than one property:

   These goods have several properties which display both active behavior and passive behavior, so meaning that they can have a greater quality-degrading/damaging effect on other goods while themselves being at increased risk from other goods.
   These goods place the highest requirements on container type, stowage space and loss prevention. For instance, green coffee beans cause odor-tainting, i.e. they release a specific odor, while being themselves extremely odor-sensitive, e.g. in relation to a citrus odor, a pepper odor etc. Moreover, green coffee beans, especially washed coffee, release water vapor while furthermore being themselves very sensitive to moisture.

13 Risk factors

Risk factors are those transport properties to which the consignor should pay attention when preparing to transport a cargo so as to minimize or rule out any possible risks from the outset.

Information in a form suited to its application is therefore required for the control and optimization of all technological operations. The information required for transport, handling and storage operations has also to be provided in the fullest possible form. See for example TIS Cargo information pages (www.tis-gdv.de) (see Section 14).

The following risk factors are examined on the Cargo information pages:

- Temperature
- Humidity/Moisture
- Ventilation
- Biotic activity
- Gases
- Self-heating/Spontaneous combustion
- Odor
- Contamination
- Mechanical influences
- Toxicity/Hazards to health
- Shrinkage/Shortage/Theft
- Insect infestation/Diseases

13.1 Risk factor Temperature

Most goods are susceptible to unfavorable temperature-induced change, i.e. quality degradation/damage. This is referred to as the temperature sensitivity of the goods.

The better the temperature in the container can be matched to the requirements of the cargo, the easier it is to maintain the quality of the cargo.

13.1.1 Travel or transport temperature

In general, the travel or transport temperature is the optimum storage temperature of a product, compliance with which ensures that the maximum storage life is achieved. For most goods not under temperature control, temperatures ranging from
5 - 20°C are deemed optimal.

On voyages into the subtropics and tropics, however, higher temperatures have to be expected, while in the winter months in temperate latitudes lower temperatures have to be expected.

Information about the optimum temperature range is of considerable fundamental importance, since it indicates that transport always entails a degree of risk.

13.1.2 Upper and lower travel temperature limits

If the upper temperature limit is exceeded, fruit and vegetables, for example, may undergo considerable quality degradation and damage due to increased enzymatic and microbiological processes. Elevated temperatures may also lead to self-heating or to cargo fire in the case of oil-containing products. Leaf tobacco which is exposed to temperatures above the upper limit, for example, may dry out, fragment and turn to dust.

Here too, it is therefore necessary to keep the cargo away from heat sources, e.g. tank tops, engine room bulkheads. If the temperature falls below the lower temperature limit, it is to be expected, for example, that fruit will suffer chilling damage (chilling) and that drinks and water-containing preserved foods will suffer expansion due to freezing.

Temperature fluctuations experienced by a cargo when traveling through different climatic zones may result in softening and melting and subsequent hardening and jamming/caking, e.g. in the case of natural rubber, bitumen, gums and resins (Japan wax, paraffin, shellac). When the container is unpacked, the caked natural rubber bales may tear.

13.1.3 Temperature-controlled transport

The above examples show that many goods cannot withstand transport without temperature control: they have either to be heated, such as many sweet oils (see Section 18.1), or chilled or frozen, as in the case of highly perishable goods. This is known as temperature-controlled transport (see Section 15).

- Temperature-controlled transport - heating

  If sweet oil cools down, it approaches its solidification point, becoming ointment-like and finally solid. This is known as chill haze (separation). This separation and the associated change in consistency occurs the more readily, the higher is the solidification point of the sweet oils. Such sweet oils need to be transported in heatable tank containers and kept at particular loading, travel and pumping temperatures. Take palm oil for example:

  Solidification range 24 - 19°C
  Loading temperature 35°C
  Travel temperature > 24°C
  Pumping temperature 50 - 55°C

- Temperature-controlled transport - chilling and/or freezing

  Highly perishable foodstuffs with a high water content and a high level of biotic activity are transported in refrigerated containers, the desired loading, travel and unloading temperatures being achieved by means of refrigeration units.

13.1.4 Loss prevention measures for avoiding temperature damage

If the upper temperature limit is exceeded for example in the case of preserved foods and of non-alcoholic drinks (in particular in glass bottles), blowing and expansion due to heating may respectively result. Heat-induced blowing is most frequently observed in the area of the container ceiling. It is therefore recommended to stow standard containers below deck and not in the vicinity of heat sources.

If the temperature falls below the lower temperature limit, the same product groups are susceptible to expansion due to freezing, so meaning that containers should also be stowed below deck in the winter months.

If ventilated containers are used, e.g. in the winter months to transport green coffee beans (from hot to cold regions), ventilation in the hold should be reduced so as not to supply too much cold air, which may lead to sweat formation as a result of the temperature falling below the dew point.

In the case of crystalline goods etc., e.g sugar, temperature fluctuations during the voyage result in caking (see Section 17.7). Transport in double-layered bags (exterior jute, interior plastic) has therefore proved effective.

To deal with temperature fluctuations e.g. on voyages in the winter months from cold to hot regions, it is recommended to pack particularly cost-intensive goods, e.g. high-quality machines, precision instruments etc., in refrigerated containers which operate independently. The thermally insulated walls of the refrigerated container put an end to the considerable temperature fluctuations, which could result in the temperature falling below the dew point, and sweat formation and corrosion may be prevented.

In the cold season especially, quick unpacking (stripping) of containers at the port of destination is essential, e.g. in the case of green coffee beans and raw cocoa. Coming from the relatively protected environment of the ship's hold, coffee cargos can be expected to retain a core temperature of 18 - 20°C.
If they are then exposed to the substantially lower external temperature, the humidity in the containers rises rapidly. Condensation on the container ceiling and the walls leads to inevitable wetting damage to the cargo.

In summary, it may be stated that the temperature sensitivity of cargoes differs widely. If there is a risk of expansion due to freezing or of chilling for example, temperature-controlled transport must be used. If the consequences of the temperature falling below or exceeding the limits are only slight, an assessment of whether the risk is worth taking may be carried out in each individual case. Help in reaching this decision may be found on the Cargo information pages.

13.2 Risk factor Humidity/Moisture

13.2.1 Classification of goods according to moisture behavior

Section 10 discussed several important terms relating to humidity/moisture, including

- Hygroscopicity
- Water content of the goods
- Sorption behavior
- Moisture sensitivity

In standard containers, goods may suffer considerable damage due to their hygroscopicity. It is therefore essential for the goods to be container dry when introduced into the container, i.e. to display a water content which corresponds to a low equilibrium moisture content below the mold growth threshold (< 75%). If the critical water content is exceeded, mold, fermentation, rot, self-heating and so on may set in. A relative humidity of 60 - 70% constitutes optimum storage conditions for most hygroscopic goods.

Section 10.2.9 made it clear that moisture sensitivity and hygroscopicity are two different concepts. For instance, a product is sensitive to moisture if even slight water vapor adsorption rapidly causes severe changes, which occur even at low relative humidities.

For example, sucrose is only slightly hygroscopic (see Fig. 5, sorption isotherm 2) but quite moisture-sensitive, because adsorption of even a small amount of water vapor results in the flow moisture point being reached and thus in liquefaction.

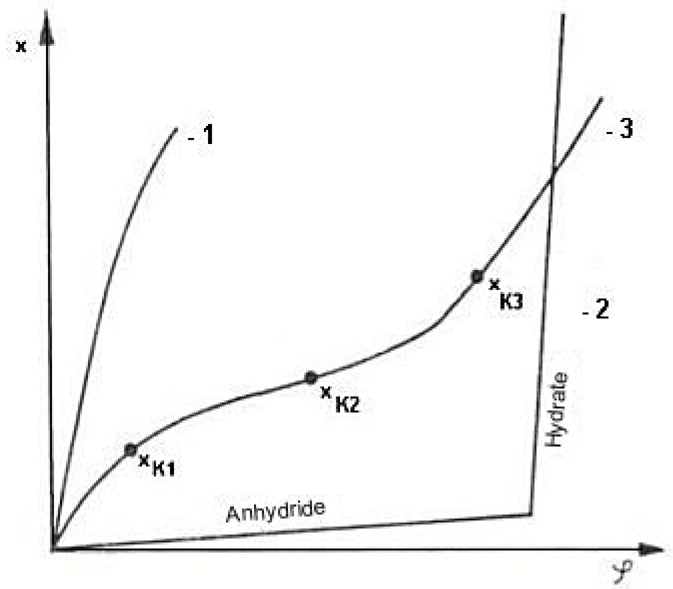


Figure 5: Types of sorption isotherms
Heiss [16]

Steel goods are not at all hygroscopic, but are highly moisture-sensitive, i.e. susceptible to corrosion.

On the basis of these considerations, it is possible to divide goods along transport-meteorological lines into four main groups.

1. Goods with a particular water content, which have the capacity to change constantly in accordance with the humidity and temperature conditions of the ambient medium. Such goods display undesirable changes due either to dampening (mold, rot, mildew stains, fermentation, deliquescence, self-heating) or to desiccation (solidification, jamming/caking, fragmentation, drying-out), depending on relative humidity and temperature.

The sorption isotherms exhibit a continuous S-shaped profile without sudden discontinuities (see Fig. 58). These include:

1.1 the overwhelming majority of foodstuffs, which are characterized by mold, rot and fermentation on the one hand and by desiccation phenomena in conjunction with loss of aroma on the other (bread and bread products, pasta products, flour and also pharmaceuticals)

1.2 hygroscopic goods, which, as living organisms separated from the parent plant, may have a tendency towards self-heating as a result of respiration processes in addition to mold, rot or fermentation (cereals, seed, oil-bearing seeds/fruits)

1.3 hygroscopic goods which, as a result of processing methods, have a tendency, due to their residual oil content and/or critical water contents, towards self-heating and frequently towards spontaneous combustion (expeller, fish meal, cereal products)

1.4 hygroscopic goods which, during storage and transport, may be subject to postfermentation as a result of previous processing methods (fermentation), as well as to usual biochemical and physical changes (tea, green coffee beans, raw cocoa, leaf tobacco)

1.5 hygroscopic goods which have been preserved by drying and have a tendency towards syrup formation and fermentation (dried fruit, such as raisins, figs, dates)

1.6 hygroscopic goods which, in addition to mold and mildew staining, may also suffer loss in strength or splitting (packaging materials, such as paper, cardboard, fibers, fibrous materials and textiles, lumber and wooden articles)

1.7 Hygroscopic goods which, in addition to mold and mildew staining, may also suffer loss in strength or splitting (packaging materials, such as paper, cardboard, fibers, fibrous materials and textiles, lumber and wooden articles).

1.8 hygroscopic finished products, which are subject to the risk of deformation, splitting or loosening of glued joints when exposed to humidity/moisture and varying temperatures (furniture, musical instruments, craft items, toys)

2. Goods which may but do not necessarily contain water, any water which may be present being chemically bound. They do not react constantly to the moisture in the ambient atmosphere, but only after a certain specific threshold has been reached, the so-called flow moisture point.
The adsorption isotherms are characterized by sudden discontinuities, of which there are as many as there are possibilities for hydrate formation. This class includes crystalline goods, which deliquesce (flow moisture point) after absorbing water vapor (water vapor adsorption) from the ambient air and may solidify and become jammed/caked (crystalline chemicals, fertilizer, salts, sugar) and harden (agglomeration) due to subsequent water vapor release.

3. Goods which do not contain any water and are incapable of absorbing water, but nonetheless suffer quality degradation or corrosion:

3.1 metals subject to corrosion, together with semifinished and finished articles without corrosion protection, including food cans

3.2 goods with a sensitive surface (optical products; clouding of lenses, sheet glass)

4. Goods which do not contain any water and are incapable of absorbing water, suffering no quality degradation due to humidity/moisture (certain plastics, industrial ceramic fittings, tiles etc.). However, losses of these goods may occur if the packaging is damaged by moisture and no longer meets transport requirements.

This list, which may be used to classify further product groups, is also relevant to the question of fitness for container transport.

Important data relating to humidity/moisture are given for each product, with appropriate references, on the cargo information pages, for instance relative humidity, water content and upper equilibrium moisture content.

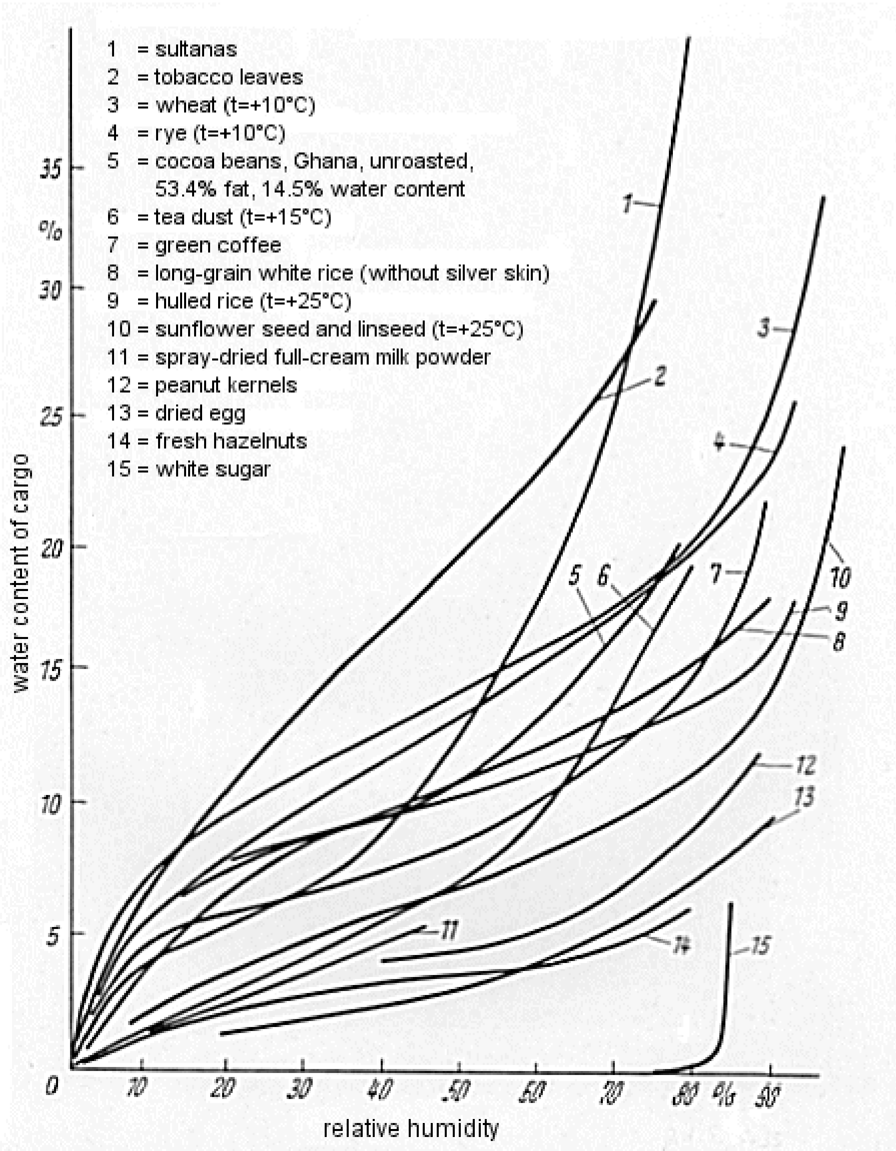


Figure 58: Sorption isotherms for various goods [27]

13.2.2 Loss prevention measures for avoiding moisture damage

Section 10.3.7 listed loss prevention measures for avoiding moisture damage in container transport, including:

- The concept of container dry goods, packaging, accompanying material and dunnage
- Perforated packaging
- Fungicides
- Mold caused by water-soluble adhesives
- Covering with paper dunnage to protect against sweat
- Covering with plastic sheets with condensation reservoirs to protect against sweat
- Suspension in a standard container of a nonwoven fabric
- Suspension in a standard container of a liner bag for bulk cargo
- Stripping of hygroscopic goods in winter
- Sealed packaging for high-quality machinery
- Pros and cons of the desiccant method
- Use of ventilated containers for high-quality agricultural products (green coffee beans)

Some more notes on the above follow below.

1. The most important prerequisite for loss-free transport in a standard container is for the cargo, its packaging, dunnage and accompanying material to be introduced into the container in a container dry state.
   It should be pointed out, however, that the cargo must not be dried to a level too far below the recommended lower water content limit, as this is associated with loss of aroma and thus odor and flavor impairment, especially in sensitive foodstuffs and semiluxury items such as green coffee beans, raw cocoa

and leaf tobacco. For instance, bay leaves take on a hay-like flavor, become brittle and finally turn to dust.

2. Packaging, for example cartons, plastic bags, should be perforated. Although in Fig. 59 (rock wool) the packaging carries the indication that the product has been hydrophobed, i.e. rendered water-repellent, a large quantity of sweat has formed inside the plastic bag, which is unable to escape due to the lack of ventilation holes.

Figure 59: Sweat inside an unperforated plastic bag

3.
4. No fresh or wet lumber should be used in case construction. The same applies if lumber is used for cargo securing measures. The optimum water content for lumber deemed to be container dry lumber is 12 - 15% (air dry lumber), the equilibrium moisture content being 70 - 80% at 20°C (see Section 19.1). However, "semi-dry" lumber, i.e. with a water content < 30%, is used in practice. Mold growth is to be expected at a water content of > 20%.

5. The corrosion protection provided by the desiccant method is ineffective if the sealed package is damaged. Therefore, all sharp-edged or pointed parts of the package contents and the case bottom have to be padded.

6. The respiration intensity of respiring hygroscopic goods, such as legumes, seed, oil-bearing seeds/fruits, is stimulated by elevated water contents or elevated temperatures. Random measurements of the water content of the product and its packaging must therefore be made prior to packing of the container.

7. This also applies to compliance with the rules relating to the stowing together of different goods: no goods with a high water content should be stowed together in a container with moisture-sensitive goods.

8. Prior to packing, it is important to inspect the container: dry floor covering, tightly closing doors, no holes or cracks (visual inspection with closed container door). When packing the container, attention must be paid to the relative humidity and temperature of the packing shed (storage location): relative humidity should not exceed 60%.

9. At winter temperatures, the containers should where possible be packed in a warehouse and/or suitable measures should be taken to reduce relative humidity in heated warehouses.

13.3 Risk factor Ventilation

13.3.1 Standard containers

In a closed standard container, the size of the openings for pressure equalization (sometimes known as fan outlets) is significant. The air exchange achieved by them is not as a rule sufficient to remove excess water vapor

being given off by a hygroscopic product. This air exchange may, however, be sufficient to cause moisture damage to a product of crystalline structure requiring dry transport. The effects are different depending on whether the product is being shipped on deck or in the hold.

Of greater significance than these "spray-tight" container fan outlets with regard to the climatic conditions in the container are leaks in the doors and roof, which inevitably appear, despite inspections and indeed sometimes only after packing, after an extended period of container transport service.

It is thus important not to view a closed standard container as being sealed against the penetration of moisture; rather, it must be expected that water may get in during introduction of the cargo. A small leak may lead to considerable damage, if batteries are in the container for example, which corrode and then cause further, secondary damage resulting from the release of acid. Every container leak is a further source of sweat.

13.3.2 Refrigerated containers

Refrigerated containers, which are examined in more detail in Dr. Wild's sections, are used for highly perishable products, since they have a controlled cryptoclimate (temperature-controlled transport) which is to a considerable extent independent of external conditions. Transport of chilled goods should be organized by experienced logistics service providers and the cargo care measures conventional in chilled goods transport should be adhered to.

13.3.3 Refrigerated containers, autonomous

Where container cargoes are transported on deck, temperature variations caused by solar radiation and night-time cooling are less severe in autonomous refrigerated containers due to the thermally insulated walls, thereby allowing certain chemicals, drinks and, most recently, high-value machines and other industrial goods to be transported in them.

Precooled cargoes can survive short voyages in these containers, while cold-sensitive fruit can withstand short periods of sub-zero temperatures without impairment of quality, especially since the fruit still releases heat by respiration processes, so raising the internal temperature.

However, on extended voyages, their effect should not be overrated: their limited heat exchange also delays desired temperature adjustment of a product. Cargo loaded when cold will arrive in tropical ports at a lower temperature than it would in a standard container. Tropical cargoes will arrive in Europe at high temperatures and will thus release large quantities of water vapor into the container atmosphere, so possibly resulting in condensation on the underside of the container roof.

13.3.4 Ventilated containers

Ventilated containers, i.e. passively ventilated containers (coffee containers), constitute an attempt to exchange hot air full of water vapor, which arises during the day, and thus to cool down cargoes coming from the tropics and to remove the water vapor they give off. Since the temperature of the cargo is higher than the temperature of the air surrounding the container, the necessary circulation of heat is maintained and moisture and heat are thereby transported out of the container (see also Section 10.3.7).

When this passively ventilated container is used to transport a cold cargo in winter from temperate latitudes into the tropics, this ventilation is ineffective, since the air flow would have to be reversed, with the hot external air having to flow downwards through the container as the cargo cooled (risk of sweat). This happens only to a limited degree, so meaning that the air exchange has to be caused by air circulation outside the container. This occurs more intensively on deck, due to the relatively high level of air circulation around the container, than in the hold, where the only air flow available is that generated by the ventilation system.

13.3.5 Open containers and flatracks

In open containers and on flatracks, the cryptoclimate largely adapts to the external climatic conditions; these containers thus provide less protection to the cargo, but also prevent a cryptoclimate unsuitable for storage from developing. The open sides or the roof may be closed with tarpaulins, so immediately forming a cryptoclimate, similar to that described for standard containers, but with greater ventilation due to the openings always present with tarpaulin covers.

If open containers are transported in the hold, a gap through which ventilation may occur remains between the upper edge of the lower container and the floor of the container stowed on top. In the case of hygroscopic goods, this constitutes an advantage over storage in standard containers.

Open containers (flatracks) packed with goods of vegetable origin and stowed in an actively ventilated hold are a special case. Stacking goods on a flatrack results in block stowage, which is well suited to ventilation in the hold. More attention will be paid to open containers in actively ventilated holds of a container or ro/ro ship when more sensitive goods are subjected to containerization.

13.3.6 Loss prevention measures for avoiding ventilation damage

1. On the cargo information pages, ventilation is discussed in association with storage climate conditions (see Section 11.3). For many hygroscopic goods, including their packaging, with a low water content (WCC 2) and 3rd or 2nd order biotic activity (BA 3 or BA 2), storage climate conditions VI are recommended, i.e. temperature, humidity/moisture and possibly ventilation conditions. This means that ventilation is not required where the goods are container dry. If goods, packaging, accompanying material and dunnage are too damp, ventilation is absolutely essential if the necessary temperature and humidity/moisture parameters are to be achieved. Since this is impossible in standard containers, damage will have to be expected from the outset with cargo which is not container dry.

2. If a container is packed with craft items in a damp season, for example, there is a risk of mold growth. This risk may be prevented by "ventilated" packaging, the cartons or plastic bags being perforated, i.e. provided with holes. The openings in the sales packaging have then to coincide with the openings in the transport packaging, so that moist warm air can escape from the packaging and air exchange can take place. To be able to achieve a ventilation effect when a container is loaded with cartons, ventilated containers have to be used. Since the ventilation openings have in each case to be located in the end faces of the cartons, the cartons have to be stowed with the ventilation holes in their ends crosswise in the container. The risk of mold due to humidity/moisture can be greatly reduced by shipping packaged hygroscopic goods in ventilated cartons.

3. In the case of hygroscopic goods of low water content (WCC 2) and 2nd order biotic activity (BA 2), such as green coffee beans, raw cocoa and shell fruit (nuts), ventilated containers are recommended, among other things to prevent the risk of postfermentation and self-heating. Care is taken to ensure that a vigorous air flow is provided to remove heat, water vapor and respiratory gases on the one hand and to supply oxygen on the other. So that the cold air flow does not cause chilling to below dew point in the winter months and thereby cause sweat to form, particular care must be taken with the ventilation measures.

4. In the case of highly perishable goods in refrigerated containers, for instance fruit and vegetables with their high water content (WCC 3) and high, 2nd order biotic activity (BA 2), the cargo information pages indicate not only storage climate conditions, i.e. temperature, humidity/moisture and ventilation conditions (SC VII) (temperature-controlled transport) but also the air exchange rate/hour, so as on the one hand to supply the goods of vegetable origin with atmospheric oxygen and on the other hand to remove harmful respiratory products, such as carbon dioxide and ethylene. Inadequate ventilation may result in fermentation and rotting of the fruit as a result of increased carbon dioxide levels and inadequate supply of atmospheric oxygen.

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13.4 Risk factor Biotic activity

Mechanical and climatic stresses are not the only stresses suffered by cargoes during transport, handling and storage that should not be underrated - biotic changes are also important.

Most foodstuffs, semiluxury items and animal feedstuffs are of natural, i.e. organic, origin, being products originating from vegetable or animal organisms. These goods interact physiologically and biochemically with their environment

13.4.1 Biotic changes and their causal factors

During transport, handing and storage, the goods are under the influence of the environment with which they correlate (interact) and consequently undergo biotic changes, of which the most important are:

- Changes due to microorganisms (molds, bacteria, yeasts), which lead to mold growth and rot
- Metabolic processes in the case of organs and organisms, such as respiration, glycolysis, autolysis
- Other biochemical changes, such as rancidity, fermentation, self-heating
- Changes due to animal pests, such as insects (beetles, moths), arachnids (mites) and rodents (rats, mice)

The causal factors are:

- Mechanical influences (throwing, dropping, impacts, jolting), which cause bruises on fruit and vegetables, which in turn act as starting points for microbial attack
- Elevated temperatures
    - promote the growth and multiplication of microorganisms to their optimum extent
    - encourage animal pests to become active, up to their maximum level of mobility
    - additionally activate metabolic processes in goods of vegetable origin
- Relatively low temperatures, which cause chilling damage (chilling) in fruit and vegetables, if the temperature falls below the lower temperature limit admissible for a specific product, e.g. brown spot diseases, loss of ability to ripen
- High water content or high relative humidity, which in particular promotes growth of microorganisms
- Influence of air composition (e.g. atmospheric oxygen, carbon dioxide, ethylene), which affects the respiration and ripening of goods of vegetable origin (allelopathy)
- Air movement, dust and microbe content of air, all of which promote infection by microorganisms

13.4.2 Loss prevention measures for avoiding biotic changes

The following measures help protect cargoes against biotic changes:

- Prevention of mechanical injury

- Slowing of activity of microorganisms and animal pests and the metabolic processes of goods of vegetable origin by reducing temperatures (chilled and frozen storage, ventilation to remove heat); this constitutes temperature control, which allows the activity of goods of vegetable origin to be reduced by "dormancy

temperatures" but necessitates the prevention of chilling damage (see Section 15).

- Hygroscopic goods and their packaging must be introduced into the container when container dry, i.e. with a water content which ensures an equilibrium moisture content in the container so as to prevent any substantial microbiological changes, such as mold and rot. If the goods enter the container with a "critical" water content, the product creates a correspondingly high equilibrium moisture content, at which microbial changes set in (mold growth threshold of φ 75%).

  Water- and water vapor-repellent packaging (e.g. wet strength paperboard) should therefore be used, cases and pallets should not be made from fresh lumber, the issue of whether to use desiccants and so on (see Section 13.2.2).

- Protection from animal pests (see Section 13.12)

In practice, the changes do not occur in isolation, but rather as combinations of different causes and changes. The criterion of biotic activity, in interaction with the environment, is important for maintaining the quality of foodstuffs from the point of production to the end consumer.

Foodstuffs, semiluxury items and animal feedstuffs are divided into four groups, according to this criterion (see Section 11.2). On the cargo information pages, each type of product is assigned to one of these biotic activity classes.

13.5 Risk factor Gases

13.5.1 Gases in goods of vegetable origin

The oxygen content of the storage atmosphere is not only reduced by the respiration of goods of vegetable origin but the excreted carbon dioxide also displaces the oxygen unless suitable ventilation measures ensure a constant supply of oxygen or removal of the build-up of CO_2, which is possible with ventilated and refrigerated containers, but not with standard containers. This phenomenon has caused cases of poisoning or even fatalities to crew members and dock workers on ships carrying cargoes of onions, coconuts, cocoa beans or sawdust.

Carbon dioxide concentrations of just 2 - 6 vol.% in inhaled air are harmful to humans, causing labored breathing. Duration of exposure is significant in determining the degree of harm: breathing air with a CO_2 content of 3.5 vol.% for half to one hour will endanger human life.

8 - 10 vol.% carbon dioxide in the inhaled air cause shortness of breath, unconsciousness and, after 6 - 10 minutes' inhalation, death.

A concentration of 20 vol.% in the inhaled air is immediately fatal.

Excessive concentrations of carbon dioxide are life-threatening to humans in two ways:

- by asphyxiation (by displacement of atmospheric oxygen)
- to a minor extent by intoxication (due to carbon dioxide's intrinsic irritant action on certain parts of the brain)

13.5.2 Gases in industrial centers

Absolute cleanliness with regard to air pollution is required in warehouses and containers which are to be packed. Hydrogen sulfide H_2S) in particular is one of the most frequent causes of damage to machinery, electronic equipment and other industrial products in many of the world's industrial zones and ports.

Hydrogen sulfide reacts with silver to form silver sulfide (Ag_2S), which results in the formation of a black film of insulating sulfides on the surface of silvered contacts and relays and on silvered conductors (e.g. coils).

Sulfur dioxide (SO_2) and sulfur trioxide (SO_3) also have a corrosion-promoting action if these gases are dissolved in mist droplets; combined with water, they form H_2SO_3 or H_2SO_4. For data processing hardware, the maximum admissible level for SO_2 is 1 mg/m³ of air.

13.5.3 Loss prevention measures for avoiding damage due to gases

Caution is advisable on sealed ramps if several containers are opened at the same, so releasing carbon dioxide. The TLV (threshold limit value) for CO2 concentration is 0.49 vol.%. Testing for the atmospheric content of carbon dioxide, oxygen and many other gases is carried out using detection equipment (multi-gas detector, see TIS).

Although in container transport the risk of an accident due to a build-up of carbon dioxide or reduction in oxygen content is minimized due to opening of the container doors, attention should still be drawn to this risk as such an accident could occur in enclosed storage areas.
13.6 Risk factor Self-heating/Spontaneous combustion

Fat- and oil-containing hygroscopic solids of organic origin with a low water content (WCC 2) and 2nd or 3rd order biotic activity (BA 2 or BA 3) have a tendency to undergo self-heating due to chemical, physical and biotic decomposition processes.

Self-heating describes the increase in temperature within an organic solid which, even in the absence of an ignition source, may result in spontaneous combustion, which occurs once the material's specific autoignition temperature has been reached without external heat input. Such goods include oil-bearing seeds/fruits and nuts (BA 2), feedstuffs of vegetable origin, e.g. pellets, fibers/fibrous materials, and feedstuffs of animal origin, e.g. fish meal (BA 3).

Causes and promoting factors of self-heating are primarily the goods' high oil content, as well as moisture, oxygen, high molecular weight, high fiber content, grain size and maturing time. Sunflower seeds, peanuts, babassu kernels, almonds, Brazil nuts, hazelnuts, walnuts, pistachio kernels and copra exhibit particularly high oil contents of > 50% (see Section 17.2).

13.6.1 Hydrolytic/enzymatic fat cleavage due to exposure to moisture

Moisture promotes both hydrolytic/enzymatic fat cleavage and biological self-heating by microorganisms. The product's elevated crude fiber content increases its readiness to absorb moisture.

Moisture, especially as a result of excessive water content, excessive relative humidity, or seawater, rain or condensation, together with heat and lipases (fat-cleaving enzymes) result in the fat in the solid in question being cleaved into glycerol and fatty acids; the fatty acids break down further into carbon dioxide and water, resulting in rancidity and self-heating which, in extreme cases, may give rise to spontaneous combustion. Thermophilic (heat-loving) microorganisms also participate in this process. Self-heating on exposure to moisture proceeds in several stages:

1. The general biological phase:

   Freshly harvested goods of vegetable origin in particular often have a water content which is higher than container dry. This water content is then at equilibrium with a rel. humidity of > 75%, i.e. above the mold growth threshold. This moisture primarily activates mesophilic molds and bacteria, i.e. those which thrive in moderate temperatures, together with those parts of the plants which are still physiologically active, resulting in the release of heat and moisture. Mesophiles start to develop at 10 - 30°C, the optimum being 20 - 37°C and the upper limit 35 - 50°C.

2. The microbiologically particularly active phase:

   At temperatures of between 40 and 75°C, the physiologically tougher thermotolerant and thermophilic (heat-loving) molds and bacteria participate in the further evolution of heat. Growth of these organisms begins at 25 - 50°C, the optimum being 50 - 65°C and the upper limit 75°C (thermotolerant microorganisms) and even 80 - 95°C (thermophilic microorganisms).
   In addition to microbial biotic activity, the heat released in conjunction with microbial activity promotes oxidation of the unsaturated fatty acids, which is in turn associated with evolution of heat. As a result, the nutritional value of the proteins is first of all impaired, which is recognizable from the incipient brownish discoloration of the goods.

3. The thermophilic decomposition phase:

   55°C is the critical temperature from which continuous temperature monitoring is required. If the temperature remains constant, there is no danger of further spoilage due to heating. The thermophilic decomposition phase proceeds at temperatures of 65 - 83°C, the vegetative cells decomposing, i.e. after the

preceding overlap of biological and chemical evolution of heat, the microorganisms die, microbial spoilage of the goods comes to an end and no further temperature increases occur above 90°C (longish temporary plateau). All vegetable and animal products containing (residual) oil are poor heat conductors with poor upward heat dissipation. Any heating of an organic product is associated with the release of water vapor and a reduction in the moisture content of the goods. The released moisture rises through the cargo as white steam and condenses on the surface of the cargo, forming a fire-extinguishing buffer on top of the cargo. Chemical degradation reactions increase in rate from 85 - 115°C.

4. The pyrophoric gas phase:

   After the temporary plateau, the chemical reactions in the cargo are resumed with renewed vigor, resulting in further heating. The cargo assumes a dark brown color. An unpleasant pungent smell penetrates to the outside as a result of protein decomposition.
   From approx. 80°C, volatile gases are released at the surface. These gases, which have a very low autoignition temperature (60°C), ignite when present in sufficient concentration and burn on the surface of the cargo with small bluish flames. However, they lack the energy to ignite the cargo. In this phase, continuing dry distillation from temperatures of 150 to approx. 200°C gives rise to gases such as phosphine, carbon monoxide (CO) and pyrophoric carbon and results in considerable losses in nutritional value, while the subsequent abrupt further increase in temperature to approx. 260°C and above is associated with a smell of charring. The presence of CO gas is considered the most reliable indication of a fire. Levels of 0.002 - 0.005 vol.% of CO in the air are deemed normal, with values rising to above 1 vol.% in a cargo fire. The lethal (fatal) dose is approx. 0.1 vol.%. Once temperatures exceed 250°C and especially 280°C, it must be anticipated that the autoignition temperature of the cargo dust will be reached. The autoignition temperature of most organic cargoes is 300 - 500°C. Usually, however, the plateau in the decomposition processes at approx. 90°C means that spontaneous combustion of the goods does not occur.

13.6.2 Oxidative fat cleavage due to action of oxygen

Food and feedstuff components frequently react with atmospheric oxygen in spoilage reactions. Atmospheric oxygen may enter into an addition reaction with unsaturated fatty acids, which is known as oxidative rancidity, through the simultaneous assistance of light, heat and certain fat companion substances, and possibly also traces of heavy metals. This phenomenon is particularly noticeable in shelled shell fruit (e.g. walnut kernels, hazelnut kernels, shelled peanuts). Storage in the dark and protection from oxygen and steel parts are necessary in order to prevent consequent brown discoloration and a rancid odor and flavor.

The principal cause underlying self-heating caused by oxidative fat cleavage is the high oil content of, for example, nuts. An elevated unsaturated fatty acid content has a strong tendency to undergo autoxidation with atmospheric oxygen to form saturated fatty acids, a process which is associated with considerable evolution of heat.

Self-heating of the goods not only damages the goods themselves (rancid odor and flavor), but also has a qualitative and quantitative impact on oil yield: the color and bleachability of the oils are negatively affected and oil yield may be cut in half.

13.6.3 Loss prevention measures for avoiding damage due to self-heating/spontaneous combustion

1. The cargo information pages (TIS) take account of the risk factor self-heating/spontaneous combustion, in particular stating the percentage oil content, as it is this parameter which has a decisive influence on the risk of self-heating.

2. Cargoes which have a tendency towards self-heating/spontaneous combustion, such as nuts, oil-bearing seeds/fruits, require a ventilated container in order to dissipate the heat and water vapor formed by self-heating and to be able to receive a supply of fresh air.

3. If self-heating/spontaneous combustion is to be avoided in container transport, water content (TIS: rapid moisture meter) and cargo temperature (see TIS) must be continuously monitored, especially during container packing. Whatever certificates may be presented, the values may have changed during prior storage and precarriage.

4. Green, wet and squashed peanuts with a high water content in particular have a tendency to undergo self-heating. Often, just a small seat of moisture is enough for heating to begin in the moist areas within a few hours. Sodden bags must therefore be rejected when packing the container.

5. When packing the container, care must be taken to ensure that the bags do not come into contact with the container walls in order to prevent oxidative fat cleavage which, especially for shelled nuts, may entail a risk

of brown discoloration and a rancid odor and flavor.

13.7 Risk factor Odor

Odor is defined as the perception of gaseous substances as the result of chemical stimuli of the nasal mucous membranes. When odor-producing substances are in the solid state (e.g. naphthalene) or the liquid state (e.g. perfume), it is only the vaporized portions which have an odor. Odor intensity is here determined by vapor pressure. Odor intensity depends upon the number of free molecules within the structure of a substance. The molecules may become attached to other substances, imparting their odor to them. Depending upon whether the aromatic substances are water- or lipid-soluble (fat-soluble), they are adsorbed to differing extents, for example, by aqueous or fatty foodstuffs. If the odor is sufficiently strong and the goods sufficiently susceptible to foreign odors, odor tainting may occur. When deciding whether different kinds of goods can be stored together, the following factors must be considered:

- the odor released by the goods (active behavior, odor tainting)
- the goods' odor sensitivity (passive behavior)
- the changes in odor intensity determined by the atmospheric conditions in the containers/warehouses (temperature and humidity)

Odors may be evaluated using the following criteria:

- Odor type
- Odor intensity

Odor type, which is subdivided into pleasant and unpleasant odors, takes account of humans' response to foods and animals' response to feedstuffs.

With regard to odor intensity, a distinction is drawn in active behavior between:

- What effect do the goods have on foods and feedstuffs?
- What effect do they have on the atmosphere in containers/warehouses?

With regard to passive behavior, goods are rated on scale running from non-odor-sensitive to extremely odor-sensitive.

The influence of temperature and vapor pressure on the odor intensity of the goods must also be taken into account.

On voyages from a cold to a warm climate, vapor pressure and thus also odor intensity increase as the temperature rises and vice versa. When estimating the odor intensity of a cargo, it is thus necessary to take account of the duration and season of the intended voyage and the climatic zones which will be passed through.

13.7.1 Odor tainting (active behavior)

In line with requirements for simultaneous storage of goods in containers/warehouses, odor compatibility is taken into account as follows:

0 - Releases no odor:
Goods with no intrinsic odor; also packaged odoriferous goods whose odor cannot escape the packaging

1 - Very slight, pleasant odor:
Goods which can be stored together with unpackaged foodstuffs

2 - Slight, pleasant odor:
Goods which can still be stored together with packaged foodstuffs

3 - Strong, pleasant odor:
Goods which release a strong, pleasant odor which rules out storage together with foodstuffs, while other odor-sensitive goods suffer no impairment of quality due to the nature of the odor

4 - Slight, unpleasant odor:
Goods which cause impairment of quality due to their slight, unpleasant odor or excessively strong pleasant

odor

5 - Unpleasant odor and/or pungent odor:
Goods which can no longer be stored together with goods which are sensitive towards an unpleasant and/or pungent odor

6 - Penetrating odor:
Odor is extremely unpleasant, completely penetrates other goods

13.7.2 Odor sensitivity (passive behavior)

0 - Non-odor-sensitive:
Goods which are insensitive to foreign odors.

1 - Insensitive to pleasant and unpleasant odors:
Goods which are only sensitive to a penetrating odor, but are insensitive to all pleasant and unpleasant odors

2 - Insensitive to pleasant and slightly unpleasant odors:
Goods which are odor-insensitive to pleasant odors of any intensity, but are sensitive to unpleasant and penetrating odors

3 - Insensitive to pleasant odors; sensitive to unpleasant and/or pungent aromas:
Goods which are insensitive to a pleasant odor, but cannot withstand any unpleasant and/or pungent aromas

4 - Highly odor-sensitive:
Goods which can still withstand a slight, pleasant odor. Odor sensitivity is comparable to that of packaged foodstuffs.

5 - Very highly odor-sensitive
Goods which can only be stored together with goods which release no or only a very slight odor. Odor sensitivity is comparable to that of unpackaged foodstuffs.

6 - Extremely odor-sensitive:
Goods which are so odor-sensitive that they may only be stored together with goods which release no odor

13.7.3 Loss prevention measures for avoiding odor taint

1. The cargo information pages (TIS), take account of the Risk factor Odor with regard to its active and passive behavior.

2. Odor elimination (deodorization) of containers and warehouses is carried out with high pressure cleaners.

3. Due to their elevated content of volatile essential oils in the peel, citrus fruits are highly odor-contaminating and must thus not be loaded together with fruit, vegetables, meat, butter, eggs and other foodstuffs, as these absorb the citrus odor, which has an effect on flavor.

4. Dunnage tainted with a citrus odor must not be reused. The odor of fruit, e.g. of pineapple or bananas, may intensify as ripening proceeds and this odor must be removed by additional fresh air.

5. Pistachio nuts usually release a slight, pleasant odor; however, if they are transported or stored without ventilation for an extended period (using a standard container), they suffer spoilage and release a strong odor.

6. Shelled shell fruit, e.g. shelled almonds (almond kernels) are particularly highly odor-sensitive, absorbing any foreign odor and becoming worthless.

7. Goods treated with insecticides, which usually release a slight, pleasant odor, such as peanuts, may absorb an off-odor due to the insecticides.

8. Some goods, such as grapes, have a slight, pungent odor due to the sulfurous fungicidal chemicals present in the packaging.

9. Semiluxury items, such as green coffee beans, raw cocoa, tea, leaf tobacco, absorb foreign odors extremely readily; they must therefore not be loaded in a single container together with each other nor with spices, cosmetics, copra, leather goods, essential oils and other goods. Tea experts are able to tell whether tea has been in a container together with such goods.

10. When eliminating odors from containers, it is particularly important to take account of the order in which cargoes have been carried, e.g. green coffee beans after a cargo of pepper. Deodorization is a fundamental requirement for the following load. An assessment of active and passive odor behavior on the basis of the above-stated odor levels is of assistance here.

13.8 Risk factor Contamination

Contamination is impairment of goods quality due to dust, dirt or fats and oils, which are primarily caused by other goods or human (anthropogenic) influences.

Contamination acts on the outside of goods and its action may be limited to the surface or may be deeper and, in extreme cases, may penetrate them completely. Contamination may take the form of localized stains, but may also extend further. Stains are localized discolored or contaminated areas on the surface of an item. Betel stains, which generate serious claims, are a particular problem.

- Contamination of foodstuffs and textiles may give rise to serious objections.
- Exposure of fibers to fats and oils may result in self-heating and a cargo fire (see Section 13.6).
- Aggressive dusts may cause particularly severe corrosion on metal surfaces.
- Leaks from barrels and canisters, residues in tank container lines, porous seals, flanges and pipework when filling tank containers.
- Paper rolls become electrostatically charged and are soiled with black dust, which results in total loss.
- General contamination in packing centers.
- LCL cargoes may not correspond in terms of packaging, e.g. fat-saturated bags with oil-bearing seeds and cartons with leather goods.
- Mixing losses due to mixing of different types of goods due to accompanying cargo (LCL containers) or cargo residues, dirty dunnage and segregating material, incorrect segregation, e.g. baled cargo with water-based paint or bagged feedstuff with toxic paints, anthropogenic contamination of goods and, finally, contamination by pests (see Section 13.12) are some examples.

13.8.1 Contamination by dust

Dust is defined as particulate air contaminants dispersed in gases and consisting of microscopically small particles of solids (frequent particle diameter 1 µm, largest particle diameter approx. 150 µm). Dust particles are transferred by air movement. Depending upon its action, dust is divided into the following types:

- gap-filling dust (flour, tobacco, lime, cement, carbon black and coal dust)
- abrasive dust (steel, silica, glass and hardwood dust)
- chemically active dust (arsenic, lead, zinc, chemically aggressive rock dust etc.)
- infectious dust (tubercle bacilli, anthrax spores)

Air in industrial zones contains on average 3,500 - 140,000 dust particles/dm^3. Many of the world's harbors are close to such centers of industry, and considerable quantities of dust may also be present in the air close to bulk cargo handling facilities.

Dusty goods do not only cause contamination, but they may also cause dust explosions, a phenomenon which must be taken into account in particular during the handling and transport of cereals and feedstuffs. All kinds of goods which release combustible dust may cause dust explosions, for example sugar, flour, cereals, mixed feedstuffs, coal, coke, lumber, sulfur etc.. The occurrence of dust explosions depends upon the nature and density of the dust and the presence of a thermal or electrical ignition source.

Dust-air mixtures constitute an explosion hazard at mixture ratios of 20 - 2,000 g/m^3 of air. The pressure wave caused by localized ignition of an explosive dust-air mixture is propagated to adjacent layers of dust, which did not in themselves constitute a risk, and swirls up further dust-air mixtures, so resulting in secondary explosions.

For the purposes of packing and storing goods together, a distinction is drawn between those goods which are merely dusty and those which create so much dust that even packaged goods may suffer damage. The same applies

to the passive behavior of the goods.

13.8.2 Contamination by dirt

Unlike dust, which is transferred by air movement, moisture plays a major role as the binder or vehicle for contamination by dirt. When moisture combines with solid particles, e.g. cargo residues, slimy, mushy or sticky substances are formed which are deposited on the surface of the cargo and, depending upon the porosity and thus absorbency of the surface, penetrate to a greater or lesser degree into the surface of the goods. The dirt mainly sticks on or may also mix with the goods. Goods in white linen cloth bags, e.g. flour, white sugar, salt, are extremely sensitive to dirt. Workers must not walk on the bags with dirty footwear during container packing.

Once dried, rain or sweat usually leave behind discolored areas, which then give rise to claims. Contamination by dust may turn into soiling on exposure to moisture.

13.8.3 Contamination by fats/oils

Fats and oils are staining substances which penetrate into the surface or upper layers of goods and cause sometimes irreversible stains or saturate the entire article. Oil degrades any cargo with which it comes into contact; even leather, lumber and marble may become completely worthless. Oil-impregnated fibers (esparto grass, hemp) and fibrous materials (cotton, cleaning rags) give rise to self-heating and spontaneous combustion.

In practice, contamination by dust, dirt and fats/oils may occur in virtually any combination with both active and passive behavior.

13.8.4 Contamination (active behavior)

In line with requirements for simultaneous storage of goods in containers/warehouses, contamination compatibility is taken into account as follows:

0 - Does not cause contamination:
Goods having no contaminating properties, i.e. which do not cause contamination by dust, dirt or fats/oils.

1 - Causes contamination by dust:
Dust is released by the goods, especially during handling, and gradually settles onto other goods. However, dust formation and the chemical properties of the dusts are generally of little significance for packaged goods, from which they may easily be removed.

2 - Causes contamination by severe dust:
Dust formation is either so severe that even packaged goods are damaged to such an extent that claims and impairment of quality are to be anticipated; or, due to its chemical properties, even small amounts of dust may cause damage, e.g. coloring earths.

3 - Causes contamination by dirt:
Dirt is contamination whose vehicle and/or binder may be considered to be moisture. When moisture combines with solid particles, e.g. cargo residues, slimy, mushy or sticky substances are formed which soil the surface of the goods. The dirt sticks on and results in claims or impairment of quality. The dirt may also mix with the goods.

4 - Causes contamination by fats/oils:
Fats and oils are staining substances which penetrate into the surface or upper layers of goods and cause sometimes irreversible stains (e.g. on marble). They may, however, also penetrate deeper into the goods and saturate them. Self-heating may occur as a consequence.

5 - Causes contamination by dust, severe dust and dirt

6 - Causes contamination by dust, severe dust and fats/oils

7 - Causes contamination by dirt and fats/oils

8 - Causes contamination by dust, severe dust, dirt and fats/oils

9 - Causes contamination by leaks

13.8.5 Sensitivity to contamination (passive behavior)

0 - Not sensitive to contamination:
These goods may be stored together with goods which cause contamination.

1 - Sensitive to contamination by dust:
These goods must be stored separately from dusty goods; dust-sensitive goods should also be protected from dust during packing, e.g. by being covered with tarpaulins or the like.

2 - Sensitive to contamination by severe dust:
These include packaged goods (e.g. in solid wooden cases) which do not suffer damage just by exposure to dust.

3 - Sensitive to contamination by dirt:
These goods must be stored separately from goods which cause contamination by dirt; if this is impossible,

they must be covered with mats, tarpaulins or the like. Dirt, which often occurs in a slimy, mushy, sticky or similar form, contaminates surfaces and may also mix with the goods in question. The goods may be rendered completely unusable.

4 - Sensitive to contamination by fats/oils:
These goods must not be stored together with goods which cause staining by releasing fat or oil. The stains penetrate into the surface or upper layers of goods and cause sometimes irreversible stains. The goods may also be saturated by the fat/oil or self-heating may occur.

5 - Sensitive to contamination by dust, severe dust and dirt

6 - Sensitive to contamination by dust, severe dust and fats/oils

7 - Sensitive to contamination by dirt and fats/oils

8 - Sensitive to contamination by dust, severe dust, dirt and fats/oils

9 - Extremely sensitive to contamination, keep absolutely clean

13.8.6 Loss prevention measures for avoiding damage due to contamination

1. The cargo information pages (TIS), take account of the Risk factor Contamination with regard to its active and passive behavior.

2. Ensuring constant cleanliness of containers, warehouses and cargo handling areas, checking goods for cleanliness, covering goods which are sensitive to contamination and avoiding storage of contaminating goods together with contamination-sensitive goods are all measures which require serious attention if damage is to be avoided during transport.

3. Contamination is best eliminated with high pressure cleaners.

4. The liner bags used for bulk cargo in standard containers (see Section 10.3.7) are used only once.

5. Container cleaning, often combined with deodorization, is a fundamental requirement for the following load. An assessment of active and passive contamination behavior on the basis of the above-stated contamination levels is of assistance here.

13.9 Risk factor Mechanical influences

13.9.1 General comments on mechanical influences in container transport

Since container transport involves multimodal carriage, the goods carried in this manner are also subject to the various stresses of the individual means of transport. When evaluating stresses, the container should be viewed as being a replacement for the cargo/load carrying area of the particular means of transport, such as case body on a truck, a freight car in a train or a ship's hold in maritime transport.

Any problems which occur in these means of transport will occur in the container too. The most frequent misconception is to view the container as a replacement for packaging, an error which repeatedly causes major losses or even jeopardizes the means of transport. The fact that, for example, a standard container is being used does not make it possible to cut down on either load/cargo securing measures or packaging.

The one exception to this is the stackability of packages. Since the container acts as a "hold" which has been designed so as to be carried in stacks in ships, packaging requirements can be simplified in that the packaging need now only be intended to withstand the stack pressures within the interior of a single container, rather than the stack pressures of 8 to 10 m of overstowed cargo in the ship's hold.

This only applies to goods which are only transported in a container and do not undergo any pre- or post-carriage operations.

If, due to their mass or dimensions, packages are not overstowed in the container, packaging requirements are

simplified as the packages are not exposed to any stack pressure. In this case, the packaging serves "only" to protect the cargo and, if necessary, to permit cargo securing.

Packaging, stowage and cargo securing in the container must be carried out such that they

- can withstand the stresses of each individual leg of the journey and
- can withstand the stresses of the individual means of transport used during the various legs of the journey.

The frequent, physical handling operations (e.g. transfer of cartons, cases, bales etc. from a truck onto a rail freight car, ocean-going vessel, inland waterway vessel and back onto a truck), which exposed the cargo to considerable risk of damage, have been replaced by much gentler container handling operations. Thanks to its standardized dimensions, the container as a cargo unit also benefits from standardized handling, a very high percentage being carried out by container bridges with spreaders.

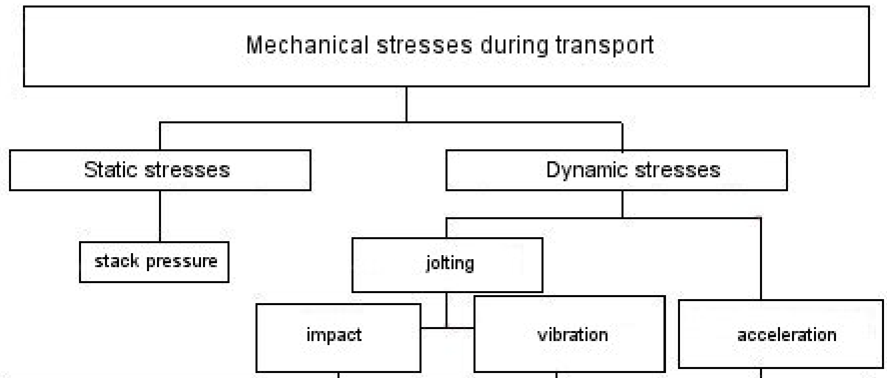
However, when containers are being packed, higher levels of stress frequently occur than was the case with conventional packing. Since closed standard containers are very frequently selected on cost grounds, goods have to be pushed into the containers and pulled out again during stripping (unpacking) due to their dimensions of mass. This is necessary because crane packing is not possible or the floor loading capacity would be exceeded if industrial conveying equipment were to be used.

13.9.2 Stresses/influences

The mechanical stresses which occur during goods transport are usually stated in fractions or multiples of acceleration due to gravity (9.81 m/s² = 1 g). Depending upon their pulse strength, even very small g values may cause considerable destruction. In contrast, very high g values acting over only a few milliseconds may have absolutely no effect on the goods.

Especially when assessing the damaging effects to the cargo of vibration and impacts, it is necessary to take the pulse length of the g values into account.

If vibration, jolting and impacts can cause damage to the goods under normal transport conditions in the planned means of transport, packaging must attenuate these effects to such an extent that damage to the goods is ruled out. Packaging specialists can devise suitable solutions to such problems.



	impact	vibration	acceleration
Railroad	Switching in transit, coupling and switching impact during switching in hump yard, kicking, travelling through swiches, rail joints	Slight while in transit, travelling through switches, when passing over rail joints, e.g. Transsiberian railroad	braking, cornering
Road	Portholes, loading from combined road road / railroad transport	While in transit depen-ding upon road surface	braking, cornering
Maritime transport	Extreme pitching of the ship in heavy weather, tipping of containers during rolling	Machinery and pro-peller vibration, hull vibration due to rough seas	rough seas, rolling, pitching, yawing
Cargo handling	Picking up and setting down by container bridges, stowing and packing in the contai-ner, pushing or pulling a container	While being carried by straddle carriers or industrial conveying equipment	Picking up and setting down by container bridges, while being carried by straddle carriers, insertion into ship cell guides

Figure 60: Mechanical stresses during transport; [Schieder]

13.9.3 Classes of mechanical stresses/influences

13.9.3.1 Static stresses/stack pressure

When transporting goods in containers, static stresses are limited to the stack pressure generated by the goods themselves. This stack pressure load is caused by overstowing of the goods. The maximum "overstowing pressure" is a function of goods height and the internal height of the container.
Vertical, dynamic acceleration forces are superimposed on these static stresses. In unfavorable stowage positions, the acceleration caused by the pitching motion of the ship in maritime transport may amount to 1 g and, in extreme cases, even more. In order to withstand this additional load, the measured static pressure (see above) must be multiplied by a factor of two. When packaging is designed or calculated, further factors such as changing humidity, "untidy" stacking etc. are taken into account. Suitable packaging experts should be consulted when planning and making packaging.

13.9.3.2 Dynamic stresses/influences

Jolting

Jolting is defined as vibration and oscillation caused by impact which then subsides. Depending upon causation (roadway, rail track, switches, rough seas transport, handling and storage operations etc.), jolting may be regular or irregular.

Impacts

Impacts are dynamic, mechanical stresses arising from the abrupt acceleration of masses. A distinction is drawn between positive and negative acceleration. Such acceleration forces are not generally repeated at regular intervals, but they do occur with greater or lesser frequency at varying intensities during transport, handling and storage operations.

Vertical impact: Tipping (by exceeding tilting moment), tumbling (rolling edge over edge), bumping (during abrupt hoisting, setting-down or bumping by other cargoes or the container by means of container bridge or on-board gear).

Horizontal impact: Jolting impacts (during switching), bumping against vehicle walls or other cargo (caused by centrifugal forces at curves and when traveling through switches, starting up).

Vibration

Vibration stresses, which occur during goods transport on all kinds of means of transport, may be divided into:

- regular and
- irregular vibration stresses

Regular vibration may be caused by the power units of the means of transport and, for example, by the ship's propeller. Vibration stresses result in shaking, chafing etc. Damage can only be prevented by suitable packaging.

Irregular vibration is generated by impacts due to unevenness of the travel way. Depending upon the nature of the travel way, e.g. abutted rails, such excitation may also cause regular vibration.

Components in machinery, computers, plant etc. are at particular risk as they may be caused to resonate by the typical vibrations of a means of transport. If this is a risk, suitable packaging experts should be consulted.

Acceleration

Negative and positive accelerations are dynamic, mechanical stresses which occur in two main groups in goods transport:

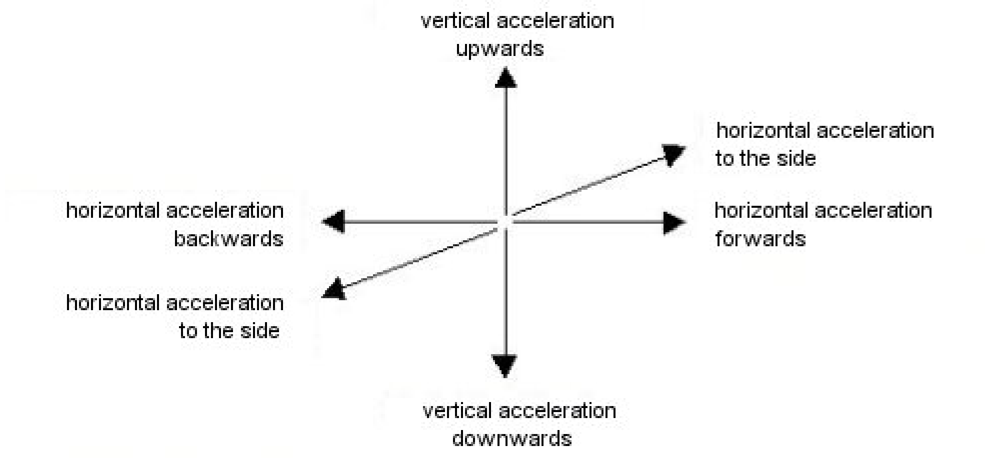
- regular acceleration and
- irregular acceleration.

Regular acceleration primarily occurs in maritime transport. Acceleration of up to one g (g = 9.81 [m/s²]) and, in extreme cases, even more, may occur due to rolling and pitching in rough seas. Such regular acceleration entails considerable load securing effort.

Irregular acceleration occurs during cornering or passage over switches, during braking, starting up, hoisting and lowering. Such acceleration forces are not generally repeated, but they may occur several times at varying intensities during a transport operation. These are the typical stresses of land transport and transport, handling and storage operations.

Other dynamic stresses are localized impact stresses: abrasion (dragging, pushing, pulling) or chafing (friction).

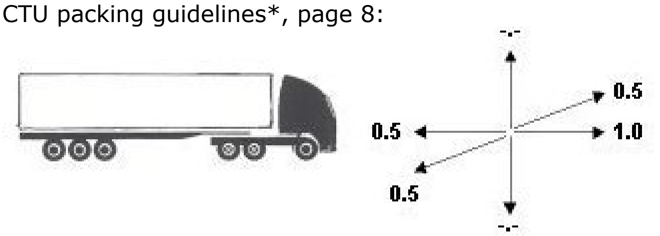
The following diagrams illustrate the various types of acceleration and associate them with individual means of transport.



Stresses in road transport:

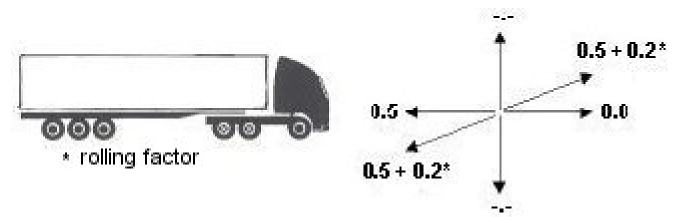
Dynamic stresses experienced in the various means of transport in g [m/s²]

CTU packing guidelines*, page 8:



*Guidelines for the packing of cargo, other than bulk cargo, into or onto cargo transport units (CTUs) applicable to transport operations by all surface and water modes of transport

VDI guidelines 2700 ff **

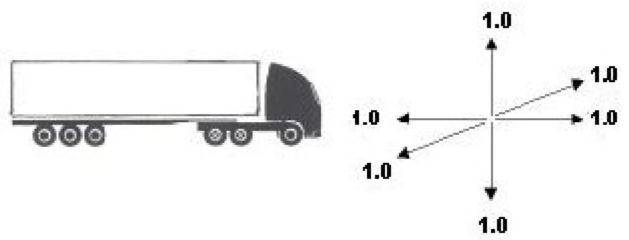


*According to VDI guidelines, the rolling factor must be taken into account for unstable loads.

**Load securing on road vehicles must be carried out in accordance with best current practice which is currently embodied, as provided in German legislation, in VDI guidelines 2700 ff.

Hafenfachschule Bremen*:

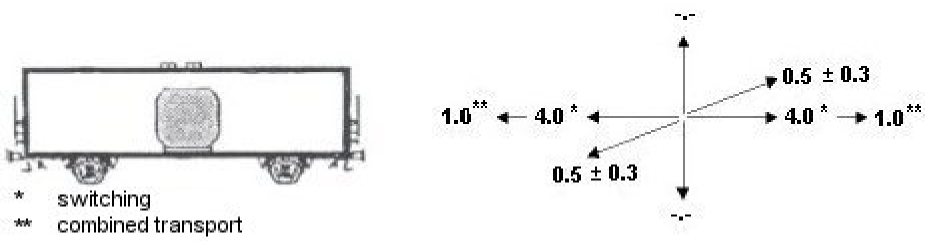
Details relating to combined sea-road-sea transport operations



*A technical college providing practical training which, for safety reasons and for simplicity's sake, recommends higher values.

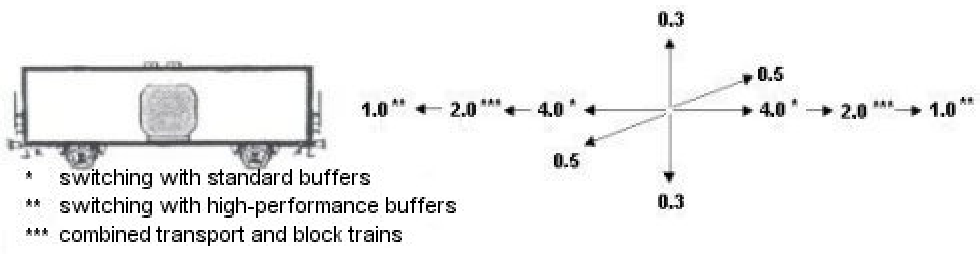
Stresses in rail transport:

CTU packing guidelines*, page 8:



*Guidelines for the packing of cargo, other than bulk cargo, into or onto cargo transport units (CTUs) applicable to transport operations by all surface and water modes of transport

GDV:



Eastern European rail transport uses semiautomatic coupling systems. To initiate the coupling procedure, these couplings require a minimum speed of 9 km/h. Since these coupling procedures are frequently performed at higher speeds due to corrosion, accelerations of up to 10 g and in exceptional cases even up to 18 g may occur.

Stresses in maritime transport:

In maritime transport, the accelerations to be expected depend on the ship's dimensions and shape, its center of gravity and center of buoyancy, its cruising speed and linear and rotational movements or the interaction of several of the above-stated movements. Examples of the movements experienced by a ship at sea are contained in the CTU packing guidelines, page 7.

CTU packing guidelines, page 8:

GDV:

In maritime transport, calculations should always be based on the least favorable assumptions. Acceleration values of 1.0 g should therefore be assumed. This also applies to securing measures relating to cargoes transported by sea in containers, road vehicles, freight cars and trailers.

German Federal Bulletin

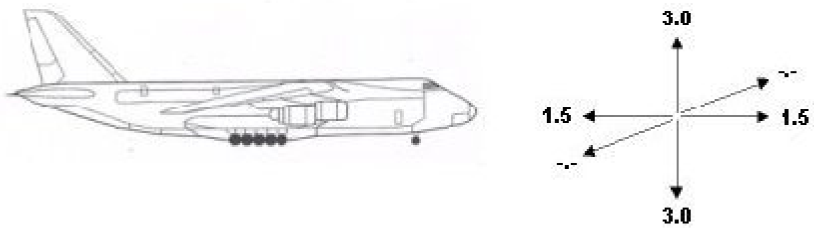
The guideline entitled "Bekanntmachung von Änderungen der Richtlinien für die sachgerechte Stauung und Sicherung von Ladung bei der Beförderung von Seeschiffen" ("Publication of amendments to guidelines for the correct stowage and securing of cargoes for carriage in ocean-going ships"), 14th February 1996, contains in Table 2 the basic acceleration values in m/s² for the various deck areas and lengthwise portions of a ship. Tables 3 and 4 contain correction factors for other ship lengths and speeds together with the ratio of width and metacentric height.

Stresses in inland waterway transport:

The accelerations arising in inland waterway transport are negligible and may be calculated on the basis of the stresses arising in road transport.

Stresses in air transport:

Delvag Luftfahrtvers. AG:



Stresses during cargo handling:

During cargo handling, stresses of 1.0 g may be assumed. Jerky lifting and setting down may generate higher g values.

13.10 Risk factor Toxicity/Hazards to health

The toxicity of many substances is such that exposure to even small doses may be harmful to human health or even fatal. Classifying poisons by their chemical composition is inappropriate because chemically related substances may exhibit all levels of toxicity from toxicologically non-hazardous to highly toxic. There is no precise classification of poisons by the level of hazard they present for either production or transport purposes.

13.10.1 Classification of poisons by their action on the human body

It is more appropriate to classify poisons by their action on the human body:

- lachrymatory (tear-producing) substances (e.g. bromoacetone, ethyl ether, bromoacetic acid)
- asphyxiants (e.g. carbon monoxide, hydrogen cyanide)
- vesicants or blister agents (e.g. mustard gas, some organic compounds of arsenic)
- cytotoxins or cell poisons (e.g. phosphorus, hydrogen sulfide)
- neurotoxins or nerve poisons (e.g. alcohols, ether, chloroform)
- organ poisons (e.g. gasoline, benzene, chloroform, mercury compounds)

Poisons can enter the human body via three routes:

- through the skin or mucous membranes
- via the digestive tract
- via the respiratory tract (inhalation)

13.10.2 Dose, quantity of harmful substance

The quantity of a poison in the body is described as the dose. A distinction is drawn between the toxic and the lethal dose. The latter ranges between 0.001 g and 0.5 g for different poisons.

The maximum admissible concentration is the concentration of a gas, vapor or dust which a human can inhale for eight hours daily, i.e. year-round constant exposure, without harmful effect. This is identical to the threshold limit value (TLV), which is the admissible concentration of a harmful substance (gas, vapor or dust) in the ambient air of a workplace. The TLV is usually stated in mg/m³.

At elevated concentrations, vapors and gases which have neither toxic nor narcotic properties may displace oxygen in the atmosphere. Air normally has an oxygen content of 20.95 vol.%; a drop in oxygen content to < 13 - 15% disrupts human bodily functions, causing headaches, reduced visual acuity, fatigue, ringing in the ears and loss of coordination.

When transporting fruit and vegetables, accidents may occur due to the build-up of CO_2.

Carbon dioxide concentrations of just 2 - 6 vol.% in inhaled air are harmful to humans, causing labored breathing. Duration of exposure is significant in determining the degree of harm: breathing air with a CO_2 content of 3.5 vol.% for half to one hour will endanger human life.

8 - 10 vol.% carbon dioxide in the inhaled air cause shortness of breath, unconsciousness and, after 6 - 10 minutes' inhalation, death. A concentration of 20 vol.% in the inhaled air is immediately fatal.

Excessive concentrations of carbon dioxide are life-threatening to humans in two ways:

- by asphyxiation (by displacement of atmospheric oxygen)
- to a minor extent by intoxication (due to carbon dioxide's intrinsic irritant action on certain parts of the brain)

The TLV for CO2 concentration is 0.49 vol. %.

13.10.3 Infection

A risk of infection may arise when transporting live or dead animals, animal raw materials and semifinished products, plants, plant parts and vegetable raw materials as well as biological preparations (vaccines, viruses, test materials). Animal diseases and pests, plant diseases and pests and vector organisms may thus occur, in any of their stages of development.

Animal diseases are diseases in animals which are caused by bacteria, viruses, protozoa or fungi and may be transmitted to animals or humans.

Parasitoses are diseases in animals which are caused by parasites and impair the health and performance of the animals and the utilization of raw materials of animal origin or represent a risk to human health. Important animal diseases are cattle plague, Asian and African foot and mouth disease, African swine fever, avian flu and African horse sickness, rabies, anthrax, psittacosis, mad cow disease (BSE) and Marburg virus.

Important diseases caused by infected foodstuffs are botulism, salmonellosis and trichinosis.

A distinction is drawn between animal raw materials and animal products: Examples of animal raw materials are hides, furs, wool, bristles, feathers, casings and horns. Examples of animal products for human consumption are meat, bones, variety meat, fat, blood and casings from warm-blooded animals etc.; animal feedstuffs include, among other things, meat meal, meat and bone meal, bone meal and fish meal.

Humans, live or dead animals, hay and straw, means of transport, packing material and bags and tarpaulins in which raw materials and products of animal origin have been transported may all carry infectious agents and pose particular risks with regard to the spreading of animal diseases, parasitoses and other particular hazards to livestock.

When transporting animal raw materials and products, the greatest risk is the transmission of anthrax spores, e.g. in animal bones, animal hair, bone meal, hides and furs and adhering dust, and of salmonellae, e.g. in certain types of fish meal and casings. Means of transport and packing materials also constitute a transmission hazard.

Anthrax is caused by the anthrax bacillus and is a notifiable febrile disease. Anthrax spores remain viable for years and may cause pulmonary and cutaneous anthrax or sepsis. Cutaneous anthrax almost always affects uncovered parts of the body, such as the arms, hands, face, eyelids or the front or nape of the neck. Slight wounds to the skin may develop into anthrax carbuncles.

Salmonellae may cause infectious, febrile intestinal and general diseases, such as typhoid, paratyphoid and enteritis. They may also be spread by sea bird and rat excrement.

13.10.4 Loss prevention measures for avoiding damage due to toxicity/hazards to health

1. The cargo information pages (TIS) suggest for all goods of vegetable origin, such as fruit and vegetables, a TLV concentration of 0.49 vol.% for the CO2 content and an atmospheric oxygen content of 20.95 vol.%.
2. Testing for the atmospheric content of carbon dioxide, oxygen and many other gases is carried out using detection equipment (multi-gas detector, see TIS).
3. Although in container transport the risk of an accident due to a build-up of carbon dioxide or reduction in oxygen content is minimized due to opening of the container doors, attention should still be drawn to this risk as such an accident could occur in enclosed storage areas.
4. Compliance with regulations for preventing, averting the further spread of and ensuring the rapid elimination of animal diseases, parasitoses and other specific hazards for livestock must be demonstrated by certificates, veterinary certificates and other similar documents which show that the animals, plants and goods are free of transmissible diseases or pests.
5. Particular care must be taken to avoid anthrax infection arising from handling animal hair and bristles, especially with imported horse, cattle and goat hair as well as pig bristles and pig wool. When handling bone meal contaminated with anthrax spores, transit through the cargo handling area must be prevented.
   Once handling operations are complete, the containers in which the bone meal was transported must be thoroughly sprayed with formalin (1% formaldehyde content). Exposure time must be at least six hours. The containers must then be cleaned and disinfected again, any sweepings being disposed of. Complete protective clothing must be worn during these operations.
6. Eating and smoking are prohibited when working with animal substances and articles. Hands must be washed and disinfected with a skin disinfectant before eating or smoking.
7. Plant importation regulations are intended to prevent the spread of plant diseases and pests. The importation

and transit of plants, plant parts and products is permitted only on submission of a certificate which must have been made out no more than twenty days before the date on which the plants or plant products left the country of origin.

13.11 Risk factor Shrinkage/Shortage/Theft

The risk factor Shrinkage/Shortage may be subdivided into two groups:

- Natural shrinkage/shortage
- Shrinkage/shortage due to technical causes

13.11.1 Natural shrinkage/shortage

Natural shrinkage/shortage or loss of volume (= weight loss) in international trade is governed by contractual agreements. Loss of volume or weight loss is regarded as damage, if the contractually agreed or commercially customary tolerance volumes are exceeded.

Natural shrinkage/shortage may be caused by temperature, humidity/moisture and other natural influences, such as drying (out), consumption by respiration processes, disintegration, turning to dust (trickle losses), volatilization in the case of essential oils and spices, shrinkage of lumber.

Further examples are:

- Loss of volume, which, in the case of palm fibers, may amount to > 2% due to drying-out as a result of seasonally induced high intrinsic moisture content.

- Loss of volume in the case of tank cargoes due to evaporation and adhesion to tank walls, residues in pipelines, valves and suction wells

- Weight loss in the case of hygroscopic goods due to drying-out of the intrinsic moisture content.

13.11.2 Shrinkage/shortage due to technical causes

Shrinkage/Shortage due to technical causes results from stresses arising during cargo transport, storage and handling. The causes are principally mechanical stresses, but may include environmental influences during transport from manufacturer/consignor to consumer. Of essential importance with regard to the avoidance of shrinkage/shortage due to technical causes are consequently the cargo's ability to resist the harmful effects of these influences (packaging) and the stresses to which the cargo is exposed during handling and transport.

Shrinkage/shortage due to technical causes may, for example, be caused by poor or damaged packaging, such as:

- inadequate packaging of high precision mechanical/optical apparatus, including the absence of necessary handling symbols on the packaging

- incorrect delivery or mixing up of bales which are not clearly marked

- excessively weak packaging, which causes bursting of bales and bundles

- bursting of steel or wire strapping and ripping of wrappings

- barrel breakage

- breakage of cases and cartons used to transport fruit

- tearing of bags and trickling out of the contents, even in the case of double-layered jute bags

- damage to bales due to rough handling with forklift trucks
- weight differences due to shortcomings in weighing methods or technology
- inaccurate volume determination in the case of tank cargoes due to the use of different methods for determining volume at points of departure and arrival.

13.11.3 Theft

As container transport has developed, so has container crime, i.e. methods and techniques are applied either to purloin whole containers or to obtain illegal access to the container contents.

Theft of containers:

- Containers on trucks are stolen during the drivers' sleep or meal breaks.
- Or they are misdirected just before reaching their destination by bogus officials.
- Forged papers are also used to obtain release of the containers from the container terminal.
- Employees of the transport companies or the importers themselves are often involved.
- Important details about the transport route of containers can also be discovered by hackers, who hack into other people's computer networks.

Theft of container contents:

- Containers are broken open, the cargo taken and the point of entry rewelded and painted over, leaving the container seal undamaged.
- If the container seal is broken open, it is replaced or repaired or grease is smeared on it to make it indecipherable.
- The procedure whereby the broken seal is replaced with a new seal with the correct number is known as the twin-seal trick.
- Padlocks have been broken open, parts of the cargo taken and the padlocks replaced with copies. It was thus impossible to determine when and where during transport the theft occurred. The fundamental problem here is that it is not uncommon for containers to spend days in the same place at terminals, on chassis or elsewhere without any supervision.
- Often, only a proportion of the cargo is taken, so the consignee thinks he has been short-shipped.
- If the entire container cargo is stolen, it is replaced with cement, bricks or barrels.

13.11.4 Loss prevention measures for avoiding Shrinkage/Shortage/Theft

Shrinkage/Shortage

If the causes of shrinkage/shortage are known, appropriate measures may considerably reduce losses of volume, for example

- by better packaging.
- by more careful use of forklift trucks by qualified personnel when packing and unpacking containers, by using clearer and better labels and pictograms on packages.
- use special metal seals on containers with loads which are at particular risk of theft.
- record the seal numbers of containers sealed with metal seals in the cargo documents.
- monitor packing and unpacking operations.

- packages which appear to have been tampered with or are misshapen should be opened and their contents checked or weighed.

- stop printing company, promotional and contents information on packages.

- always use sufficiently thick shrink films on palletized goods.

- use packaging which complies with the modular system, i.e. length and width must be adapted to the container.

- in the case of particularly high value and sensitive appliances, such as computers, IT products and/or IT components, shock indicators should be incorporated into or attached to the packaging. If these indicators have been triggered in transit, the package contents must be inspected immediately.

- containers with particularly valuable goods must stowed with the doors of adjacent containers facing towards each other.

- apply UN ECE Guidelines for Packing of Cargo Transport Units, which have been published by the IMO and ILO.

Theft

Security companies may be used to avoid theft. An appropriate security company should be selected depending on whether the transport operations are national or international. Well-known security service providers carry out a pre-transport analysis to identify and eliminate any organizational weaknesses. Particularly valuable cargoes, such as IT products, computers, computer chips etc. are additionally guarded or accompanied.

- Particular attention must be paid to how the container doors are secured, for example with locks and seals; e.g. seals may be in the shipping company's colors or high security locks may be used.

- There is only very limited scope for the use of container locks due to the customs issues which arise when crossing borders. Container locks are used for domestic transport operations and for the transport of customs-cleared containers within and outside Europe.

- "Heavy duty" seals are disposable seals which are recommended for maritime transport.

- Bar locks, which lock the container door locking bars together, are also used for valuable cargoes.

- Devices are also welded onto the container doors for locking the container's locking bolts or bars.

- Other professionals use wire rope clamps instead of a lock. Once the wire clip has been fastened to the door bolts, the threads or bolts are damaged in such a way that they can only be removed with a heavy duty cutter/angle grinder.

- Padlocks may be more successfully used if they are enclosed in narrow metal tubes shrouding the locks. In this way, neither bolt cutters nor angle grinders can be used to attack the lock without first destroying the metal tubes.

To summarize:

As levels of criminality rise, it may be assumed that there will be ever increasing demand for appropriate solutions for securing valuable container cargoes. Selecting a properly qualified logistics service provider is essential to ensuring secure transport.

13.12 Risk factor Insect infestation/Diseases

13.12.1 Damage caused by storage pests

The protection of stored commodities entails the protection of goods against spoilage by animal pests. Storage pests include beetles (granary weevil, rice weevil, copra beetle), moths (dried fruit moth, Angoumois cereal moth, European grain moth), mites (grain mite) and rats and mice. They accompany the goods from when they are harvested until they are processed or even to the point of consumption. They start to multiply before transport, continue during the voyage and do not stop even during storage and processing.

Storage pests have found themselves carried passively, i.e. by the means of transport, to completely new biotopes, where they have thrived. Originally from the tropics and subtropics, they have spread to temperate latitudes.

When a product is transported from the country of origin to the country of consumption, it generally passes through climatic regions which greatly favor storage pest multiplication.

It is the task of the transporter, therefore, to use his knowledge of the living conditions of the pests to protect the goods entrusted to him. These measures are very varied and include both preventive inspections and active pest control.

Storage pests cause a wide range of damage.

The following types of damage are of major importance:

- damage to the cargo caused by eating
- contamination of the goods by excrement, shed skins, webs/gossamer, laid eggs, live and dead pests
- one pair of granary weevils may produce approximately 4,000 offspring a year, which will between them eat 4 kg of cereals and contaminate 4,000 - 40,000 kg of cereals
- promotion of microbial spoilage
- the chewing damage caused by pests brings about increased respiration in goods of vegetable origin and this, associated with the metabolic activity of the pests themselves, promotes evolution of heat and moisture, which in turn provide favorable living conditions for molds and subsequently, at very high moisture levels, possibly also for bacterial growth
- transportation of diseases and the consequent impairment of quality and/or disinfection costs
- financial burden caused by the fumigation required and the associated time losses for the transporter

13.12.2 Living conditions of storage pests

Food sources

Some pests are associated with particular food sources, e.g. clothes moths and fur beetles (monophagous). Most storage pests occur in almost all foodstuffs and animal feeds (polyphagous). The fact that storage pests are not generally associated with a particular product as food source may be illustrated by the copra beetle (Necrobia rufipes): copra is indeed frequently infested by the copra beetle (also known as the red-legged ham beetle), but it and its larvae also infest casings, dried fruit, peanut cake, figs, furs, hides, cheese, cocoa, coconut cake, desiccated coconut, dried egg yolk, dried meat (sausage), ham and bacon.

Copra infested with copra beetles must therefore not be stowed in the same container as the goods listed above or stored near them in a warehouse.

Cockroaches not only eat foodstuffs but also paper, textiles and leather goods.

Rats may likewise inflict considerable damage not only on foodstuffs but also, for example, on bales of silk.

Significant damage has also been caused by, among other things, the tobacco beetle (Lasioderma serricorne), which has been known to migrate from copra flakes to tea chests. Fumigation of the tea chests impaired the quality of the product by 50%, as well as being in itself a costly process.

They are also to be found in packaging material (barrels, cases, fabric wrappings).

It should also be pointed out that storage pests can go without food for extended periods. The khapra beetle (Trogoderma granarium), for instance, can manage for around a year without food (see Fig. 61).

It should therefore never be assumed that all pests are removed when a container is unpacked or a warehouse is emptied. Even if several voyages are then made carrying goods which are unsuitable as food sources for storage pests (paper, machines, porcelain etc.), fumigation should still be carried out. If a container is then once again packed with suitable goods, the pests will be very greedy after their long period of starvation and will cause a particularly large amount of damage.

Figure 61: Khapra beetle

Temperature requirements

As far as temperature requirements are concerned, a distinction may be drawn between warm-blooded (homeothermic) animals and cold-blooded (poikilothermic) animals.

Warm-blooded animals, such as rats and mice, control their vital functions by maintaining a constant body temperature. Rats and mice can therefore manage easily even in refrigerated containers or cold stores.

Cold-blooded animals, which include insects and thus the majority of storage pests, are dependent to a great extent on external temperatures. Their metabolic functions, such as respiration, food intake, mobility and multiplication, are highly temperature-dependent, as is clear from the optimum curves in Figs. 62 and 63.

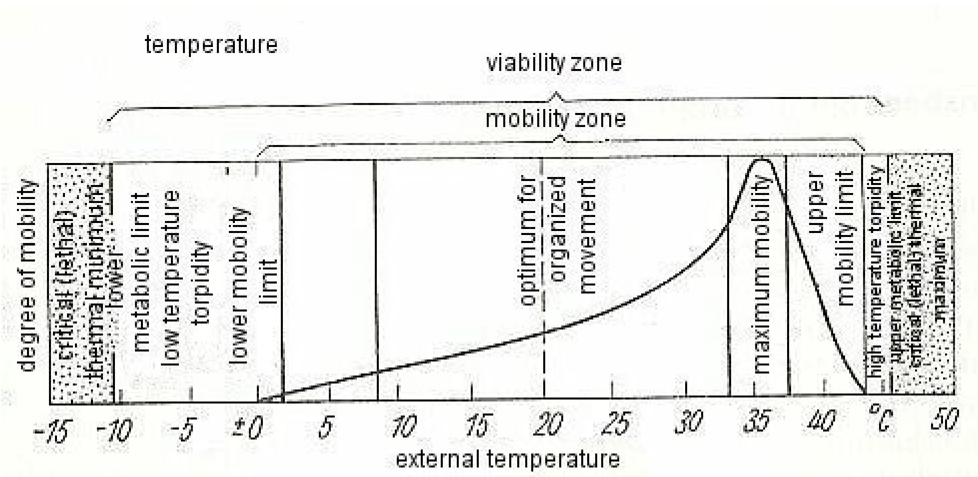


Figure 62: Insect mobility as a function of external temperature and limits of viability
Herrmann [17]

Figure 62, which illustrates the mobility curve and temperature limits for insect viability, provides the following information:

There is a close relationship between temperature and metabolism. As temperature increases, the rate of chemical and enzymatic reaction and thus the metabolic rate of the body increase, so improving the mobility of the animals. The mobility zone ranges from 0 - 45°C, the optimum for organized movement being 20°C and maximum mobility being present at 37°C. It is possible to conclude from this that, as the temperature in the container rises, the risk of storage pest infestation of neighboring batches of cargo is increased. Maximum mobility is quickly exceeded, however, with the curve falling steeply from 37°C to 45°C, the reason being that the enzymes suffer increasing damage at elevated temperatures due to protein denaturation, leading ultimately to death due to overheating (critical (lethal) thermal

maximum 45 - 50°C). Insect infestation may therefore be combated by heating to a temperature which kills the insects (70°C).

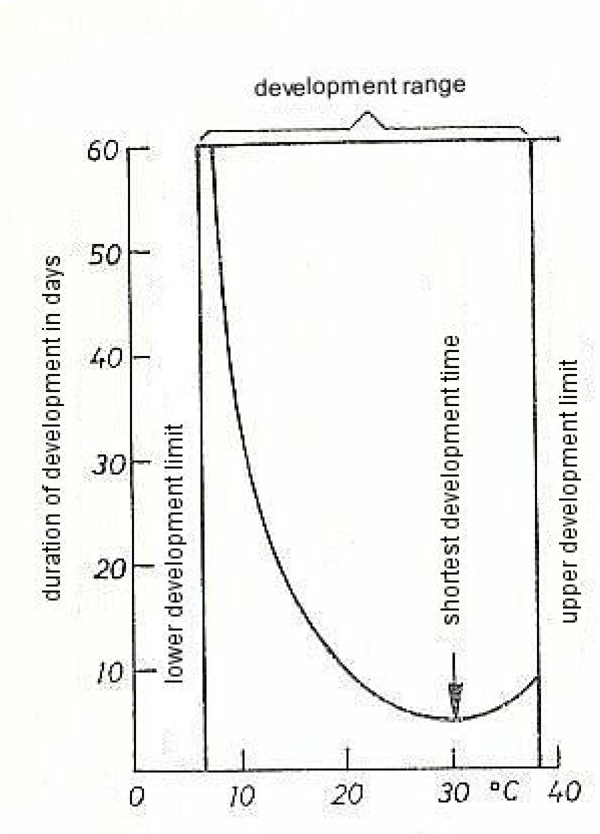


Figure 63: Duration of development of meal moths as a function of temperature
Herrmann [17]

At low temperature, metabolic processes diminish, resulting in a slowing of movement, until the lower mobility limit of 0°C is reached. Finally, low temperature torpidity is reached, all vital functions stop and death occurs as a result of the cold (critical (lethal) thermal minimum) if freezing occurs. Poikilothermic pests are therefore of no relevance in refrigerated containers.

In general, the lower mobility limit is 5 - 10°C, while some insects suffer low temperature torpidity at temperatures as high as 15°C.

The individual stages of development of storage pests, such as eggs, larvae and imagoes (fully developed insects), also proceed with regard to duration in the manner of an optimum curve, as shown in Fig. 63 for the development of meal moth eggs. This illustration reveals that at 30°C the eggs need only approximately five days to develop, while the duration of development is extended to thirty days if the temperature is reduced to 10°C.

The vital optimum temperature, at which the number of offspring is at its greatest and mortality at its lowest, i.e. when cargoes are at their greatest risk of animal pest infestation, is between 25 and 30°C.

Life span is not as closely related to temperature as is metabolic activity. Low temperatures and thus a reduced metabolic rate may even increase life span.

Complete withdrawal of food is therefore better tolerated at low temperatures (life span of granary weevils at 5 - 6°C approximately twelve months) than at higher temperatures (life span of granary weevils at 8 - 20°C approximately two to three months), meaning that a temporary lack of food is not lethal.

The comfort or preferred temperature indicates what temperatures animal pests prefer if given a choice between holds kept at different temperatures. Animal pests coming from the tropics prefer higher temperatures than those from temperate latitudes. This would suggest that the greatest damage caused by animal storage pests is to be expected in tropical zones or, in cooler climatic regions, during the warm season. However, it is important to bear in mind that animal activity may also occur in the winter months if heat and moisture evolve due to severe pest infestation.

Humidity/Moisture

In addition to temperatures, water content and relative humidity are also significant. On the basis of humidity/moisture requirements, a distinction may be drawn between two groups:

- insects to which elevated humidity values are essential to prevent drying out, e.g. cockroaches, silverfish, plaster beetles, cheese mites, grain mites and which may be killed if moisture is withdrawn.
  Flour or cereals with a water content of < 12% (air equilibrium moisture content 55%) cannot any longer be infested by the grain mite.

- insects which can develop on a relatively dry substrate; cereal pests, for example, require a water content of only 14% and a relative humidity of 70 - 75%. It can be concluded from this that dry storage and low temperatures offer good protection against animal infestation.

When packing containers, fresh wooden dunnage must not be used, as this could be infested with horntails. The hatching insects will chew their way through any type of textiles, for example, and may thus inflict considerable damage on textiles (ready-made garments) and textile bales.

Habitats

A characteristic feature of animal storage pests is the way they seek out nooks and crannies. This is caused by two factors:

- a degree of photophobia, causing them to withdraw into crevices and slits when exposed to light

- touch stimuli (thigmotaxis), causing them to respond by changing their location. Thigmotaxis causes insects to try to surround themselves with solid walls on all sides, so meaning that they will withdraw into nooks and crannies even in completely dark holds (e.g. cockroaches, woodlice).

The described living conditions define the preferred habitats. A microclimate which is particularly appealing to animal pests includes warmth, moisture and protection from drafts and light. The cargo itself provides the primary habitat. Factors which may cause the pests to migrate en masse from their original location include overpopulation, shortage of food, a variation in microclimate and the addition of a cargo which is more appealing as food. The idea that goods unsuited to pests (machines, porcelain, glass) would not be considered as habitats is mistaken; general cargo transport packaging, with its protective coverings of straw, wood wool, corrugated board and sawdust, provides many species with good opportunities to colonize and reproduce. Empty containers or empty storage areas may accommodate large numbers of storage pests.

They are then ready to infest newly accepted cargoes, which is why containers must be absolutely clean before acceptance of a consignment.

Habitats may also be changed as a function of pest metamorphosis. For example, imagoes (imagines) seek out new places as breeding grounds for laying eggs, while larvae seek out pupation sites. In this way, damage sometimes occurs during transport which is not caused by pests typical of the particular type of cargo but rather by "migrants" from accompanying cargoes. The risk of such damage is the greater, the longer the route and duration of transport. Some examples follow:

- In one instance, a large number of bacon beetle larvae (Dermestes lardarius) migrated from the salty, damp environment of animal hides, which they needed for development during the larval stage, into the accompanying cargo of viscose staple fiber bales, so as to undergo their metamorphosis in the dry cloth bales. Pupae and hatching beetles were found there, so turning the migrant bacon beetle into a textile pest.

- Severe damage was caused to a batch of pullovers from East Asia. A third of the pullovers displayed eating damage caused by red-legged ham beetles (Necrobia rupifes), which had hatched out of a consignment of copra and multiplied considerably in number. In their search for new breeding grounds, the beetles had got into wooden cases and thence through metal foils, cartons and finally through plastic bags into the woolen goods. As this environment did not appeal to them, they tried to chew their way back out and, in so doing, caused considerable destruction to the pullovers.

- Larvae from the yellow mealworm (Tenebrio molitor) migrated during transport from an accompanying cargo of flour and rolled oats into a consignment of pullovers, for pupation.

- The larvae of the tobacco beetle (Lasioderma serricorne) do not restrict themselves to tobacco leaves, but instead have been known also to destroy the packaging material made of hard sacking.

- Horntails may migrate from fresh lumber into textiles - the hatching insects will chew their way through any type of textiles.

From these examples, it may be concluded that, especially on long voyages, it is essential not to stow foodstuffs and semiluxury items, hides and furs together in a container with textiles of any kind.

13.12.3 Detecting storage pest infestation

"Hidden" or "internal" infestation:
Frequently, a cargo which is packed in an apparently uninfested state is found to be infested when the container is unpacked. The reason for this is that seeds, legumes and the like contain eggs which develop during the voyage. This is known as hidden or internal infestation.

Infestation can be recognized from:

- the holes eaten in grains and seeds, see Fig. 64
- inspection of the packaging material

Figure 64: Green peas. The arrows indicate peas infested by the pea beetle (Bruchus pisorum).

In the case of bagged goods, the bag seams are particularly sought out by the larvae of the khapra beetle and of the cadelle beetle and by some other kinds of beetle.

Indicators for recognizing the most important species:

- Pin head-sized round holes in infested granular goods are indicative of drugstore beetles.
- Round holes and irregular, eaten-away pits indicate granary weevils and the like.
- Grains stuck together with gossamer threads, often with lumps of excrement, are indicative of moths.
- Grey dust on and between goods and a honey-like odor are indicative of mites.
- Milled products which have lumps held together by gossamer threads are infested by moths.
- If they have pea-sized, often somewhat elongate lumps (egg cases) with larvae or pupae, the drugstore beetle is responsible.
- Fur beetles can be recognized by the roundish, closely spaced eaten-away areas. There are no traces of gossamer threads.
- Cereals with an increasing temperature or a musty odor may be infested by granary weevils, rice weevils, flour beetles or other species of beetles. In this case, the level of infestation is then relatively high.
- Holes or crumbly excrement on dried fruit are indicative of sap beetles.
- Legumes with small round windows only covered by the seed coat contain bean weevils and the like.
- Round "exit holes" without a lid, on the other hand, are indicative of drugstore beetles and lesser grain borers.

13.12.4 Types of insect infestation of packaged foodstuffs

- Penetration of the packaging used - insects with strong jaws (mandibles) launch a direct attack on the packaging material and chew away holes big enough for their body size. Since smooth surfaces offer little purchase, creases, seal seams, embossed patterns and other weak points are preferred. The lesser grain borer is particularly active.
- Invasion through faulty closures - insects with weak mandibles (moths) head for gaps in the packaging. The dried fruit moth is particularly active.

13.12.5 Loss prevention measures for avoiding insect infestation

If pesticides have to be used, this must be done before loading or on arrival of the container. After using chemicals, the container must be labeled in accordance with the IMDG Code. Although the goods themselves are not hazardous, the appropriate guidelines must be followed, e.g. the goods must be well ventilated and inspected at the port of arrival.

The common packaging materials paper, cardboard and paperboard (corrugated board is the most susceptible) and most plastic films do not offer full protection against insect infestation. Previous test results have shown that hard PVC or thicker polyethylene films (PE films) are sufficiently resistant to insect attack.

Packaging materials can only be impregnated with insecticides in the case of industrial products (textiles); in the case of foodstuffs, food safety legislation must be complied with.

Insect-tight packaging should be used for transporting foodstuffs into the tropics, since massive insect infestation is a likely prospect.

Transport of goods infested with pests is only permitted if they are packed in such a way as to ensure that the pests do not migrate to uninfested goods. It is forbidden to transport infested goods in the same container as uninfested foodstuffs and semiluxury items.

Pest-free foodstuffs and semiluxury items must not be packed in containers which contain pests.

A container may be designated pest-free if no pests are to be found in the nooks and crannies accessible from the container and on the goods already packed.

The experience gained about the habits of storage pests has shown that the best conditions for storage (cool, dry and airy) are also the best when it comes to avoiding pest infestation.

Since, in practice, temperature regulation is not possible to the necessary extent, the main emphasis is on the second of these conditions:

It is imperative that goods are not stored in excessively damp surroundings.
Dry storage eliminates a number of troublesome pests (mites, European grain moth etc.) from the outset.

Order and cleanliness constitute the first principle of storage. Cargo residues must not be left in containers or warehouses.

Figure 65: Trap used to identify pests;
Photo: Schieder

The following three groups of methods pest control will now be explained.

1. Mechanical methods of control:

   These include cleaning goods in storage areas and cleaning containers.
   Traps are sometimes also used, for example to identify pest infestation of tobacco (see Fig. 65).

2. Physical methods of control:

   Pest infestation may be combated by cooling or heating, depending on the temperature requirements of the pests. The most effective method for killing pests is repeated raising (70°C) and lowering of the temperature. However, this method is not feasible in the case of container transport.

3. Chemical methods of control:

   These are currently the most important methods. The following insecticides are classified according to the manner in which they are assimilated by the pests:

- Stomach poisons
- Fumigants and
- Contact poisons (contact insecticides).

- **Stomach poisons** are of only subordinate importance. Bait laced with stomach poisons is harmful to humans.

- **Fumigants** are gaseous respiratory poisons which are breathed in. Fumigation is at present the most widespread method of pest control, since gases, such as phosphine (phosphorus hydride, PH_3), hydrogen cyanide (HCN) and methyl bromide (CH_3Br), are the most effective pesticides and leave the smallest quantities of toxic residues. To combat rats, fumigation with hydrogen cyanide is by far the most effective method.

There are two approaches to combating cockroaches:

using agents with a certain long-term effect, which present a toxic hazard to humans for a relatively long time, and using agents which have an immediate effect but which decompose or volatilize rapidly and lose their toxicity soon after use. Standard containers on long voyages merit particular attention.

Spray or fumigation agents have the following advantages and disadvantages with regard to use:

Dusting or spraying of insecticides into the cargo to be disinfested has the advantage of providing relatively long-term protection against new infestation; the disadvantage is the toxicity of these insecticides, which leave persistent residues in the cargo.

The advantage of pesticidal fumigation agents is that the gases are better distributed in the cargo stacks, so that hidden pests and pests in the various stages of development may be killed. Virtually no toxic residues remain in the cargo.
Fumigation agents should not be expected to be very effective at low temperatures, because the pests fall prey to low temperature torpidity and respiration is limited severely. It is therefore important for the temperature to be as high as possible during fumigation.

Fumigation with methyl bromide (CH_3Br) against insect infestation in containers:

Methyl bromide is a low boiling gas (4.5°C), which consequently evaporates rapidly.

Containers which have been fumigated with methyl bromide must be labeled as such. Fumigation with methyl bromide is conventional in Europe and in the Far East. All fumigation contractors must be recognized and make out appropriate certificates after fumigation.

Fumigation takes three days:

1st day:	fumigation is performed
2nd day:	the gas remains in the container
3rd day:	container is opened, ventilation being effected passively by opening of the container doors.

Contact insecticides have more recently achieved a certain significance. They kill the pests merely on contact. The outer skin of the insects consists of chitin, which forms a very thin layer on the joint membranes and at the sensory cells (feelers, legs, mouth parts), so allowing uptake of the poisons. Successful combating of pests with contact insecticides requires a knowledge of the pests' habitual pathways. These pathways are coated with the contact insecticide and finally the numerous dead insects are brushed away.

13.12.6 Taking account of insect infestation when packing a container

If a container is properly packed with defect-free goods, damage caused by animal pests or microorganisms is unlikely. Such damage can virtually only occur to a cargo located in a closed, intact container if an infestation was already present on packing. This gives rise to the following requirements:

1. Particular attention must be paid to quarantine pests or quarantine diseases, i.e. organisms which are harmful to plant life, which, through the importation of seed, live plants or plant parts, may be transferred from their native countries into countries and continents where they did not previously occur. The occurrence of all quarantine pests and quarantine diseases is notifiable.

2. Only clean containers suitable for the cargo should be packed, with particular attention being paid to the container floor. In the case of maritime transport to, among other places, Australia and New Zealand, quarantine regulations also apply to wooden components. The lumber used for crates and cases must have been treated against pests, especially the sirex wasp, and certified. New Zealand, for example, requires the lumber used for crates and cases to be free of insect infestation, fungal attack and bark residue.

3. Order and cleanliness in warehouses. Do not leave partially packed containers open for extended periods.

4. Use only healthy or impregnated lumber for packaging, segregation and securing purposes. This also applies to paperboard, paper, chipboard and similar material.

5. Comply with the measures for avoiding high relative humidity in the container. Temperature conditions may favor the habits of many pests or the growth and multiplication of microorganisms.

6. Use refrigerated containers for highly perishable products.

13.12.7 Diseases

On the cargo information pages, the section Risk factor Insect infestation/Diseases covers not only insect infestation but also those diseases of foodstuffs, semiluxury items and animal feedstuffs which are harmful, for example

- Anthracnoses (fruit rot, black rot or tip rot) in bananas
- Blue mold rot or storage rot in citrus fruits caused by green mold and blue mold
- Grey mold rot or Botrytis rot in grapes
- Alternaria spots on cauliflower and Brussels sprouts
- Onion neck rot caused by the mold Botrytis allii
- Fusarium rot in certain types of vegetable and potatoes
- Psychrophilic spoilage in meat etc.

In industrial goods, only the risk factor insect infestation is considered, and then only because "migrants" may sometimes be found, in particular in packaging material.

14 Cargo information - an online system for transport professionals

14.1 Cargo information as part of the Transport Information Service (TIS)

Machinery/equipment/appliances:

- Household appliances/white goods
- Machinery, machine parts
- Switch cabinets/switchgear
- Home entertainment equipment/brown goods

Metal/Steel products:

- Steel sheet in coils
- Steel sheet in sheets
- Profiles
- Pipes
- Wire rod

Products/raw materials of the semiluxury item and food industry:

- Coffee, green coffee beans
- Cocoa beans, raw cocoa
- Tobacco, leaf tobacco
- Tea
- Preserved foods, general
- Chocolate, solid
- Mustard
- <u>Beverages:</u>
  - Beer
  - Rum
- <u>Sugar:</u>
  - Candy sugar
  - Raw sugar
  - White sugar
  - Lump sugar

Fruit/vegetables/nuts/foods of vegetable origin:

- <u>Fruit, fresh:</u>
  - Pineapple
  - Apples
  - Avocados
  - Bananas
  - Pears
  - Clementines
  - Nutmegs

Alfalfa pellets
Corn pellets
Rice bran pellets
Soybean meal pellets
Sunflower pellets
Wheat bran pellets
Wheat mill run pellets

Lumber/Lumber products:

- Veneer
- Roundwood
- Cut lumber

Paper/Semifinished lumber products:

- Waste paper
- Roofing felt
- Filter paper
- Photographic paper
- Cardboard
- Packing paper
- Paper bales
- Millboard
- Waxed paper
- Corrugated board
- Newsprint
- Cellulose/chemical pulp

Textiles/Textile products:

- Clothing/ready-made garments
- Yarns
- Fabrics/cloth/textiles
- Carpets

Vegetable-derived fibers, textile fibers, basketwork materials and cushioning materials:

- Cotton
- Esparto
- Flax
- Flax tow
- Hemp

Jute

Kapok

Coconut fiber

- Manila hemp
- Palm fiber
- Piassava
- Raffia
- Ramie
- Sisal hemp
- Chair cane
- Absorbent cotton
- Cellulose/chemical pulp

Animal-derived fibers and textile fibers:

- Combed top
- Silk
- Wool

Cereals:

- Barley
- Oats

- Corn
- Rice
- Rye
- Wheat

Spices:

- Aniseed
- Apricot kernels
- Chilies
- Fennel seed
- Cloves
- Ginger, fresh
- Ginger, dried
- Cardamom
- Garlic
- Coriander
- Caraway
- Bay leaves
- Mace

- Trucks
- Automobiles

The German transport insurance market has always been primarily a cargo insurance market. Thus, the loss prevention work carried out by the Loss Prevention Committee (competent section of the Transport technical committee within the Gesamtverband der Deutschen Versicherungswirtschaft e.V. (GDV, German Insurers' Association)) primarily focuses on the cargo. Since the turn of the century, information about different goods has been collected and published, so as to prevent losses caused by incorrect treatment or storage during voyages. Since every loss of quality suffered by a cargo means an insurance loss, the first aim of transport must be to supply the cargo to the receiver without any impairment of quality. As transport speeds have increased and the various means of transport have become more high-tech (ventilation, refrigeration, heating), it has become possible to transport sensitive goods. The interest in this type of transport is very great, since such goods are, and always have been, lucrative for the ex- and importer. For transport companies (shipping companies, carriers, handling companies etc.), this type of transport is of interest, since higher freight rates can be obtained than for non-sensitive goods due to the higher level of cargo care (ventilation, refrigeration, heating).

Depending on the terms of the contract, the risk is shifted from the ex- or importer to the transport insurer. This explains the cargo insurers' strong interest in loss-free transport. As the means of transport have become more high-tech, it has become possible to transport more sensitive, high-quality goods. The risk of spoilage or loss of quality, which may be equated with an insurance loss, has historically been and still is shifted onto the transport insurer. Thus, the transport insurers' need for information about different goods and how to transport them without loss has increased.

At the beginning of the 1990s, the Loss Prevention Committee decided to set up an electronic information system containing the above-stated extensive information about goods and means of transport.

14.2 Methodology

The cargo information is based on two sources:

1. the cargo handbook "Die Ware in der Transportversicherung" published by the former DTV (new edition 1990-1994) which covers approximately 140 types of cargo

2. the "Codierte Handbuch der Güter des Seetransports", which was produced in three volumes at the former Warnemünde-Wustrow University of Seafaring (1969-1989), covering 600 main product types and 2,600 cross-referenced product types.

A common feature of the two works is the provision of information about goods to be transported, protecting them from damage and assessing the risks associated with transport by ship, rail, truck or aircraft.

The cargo information pages have been drafted on the basis of the above two works, together with current specialist literature from GDV's transport division. With the emphasis on ensuring that all information is up-to-date, experts have been consulted and use has been made in particular of the transport insurers' information services. New technologies, in particular with regard to container transport and controlled atmosphere container transport, new packaging, analysis of incidents of loss and finally photos and drawings have all been included in this work.
14.3 Structure of cargo information contents

The details given in cargo information about the individual products are arranged in a clear structure according to risk factors which may influence the quality of the product during transport. Internet technology allows quick selective access to individual risk areas. Further helpful specialist information is available by intelligent linking to other areas of TIS. Thus, the information relating to a product may be limited to the individual risk factor, without having to omit more detailed specialist information.

The transport properties of goods are illustrated by means of an extensive checklist. The first part of the cargo information contains general information about the product, such as product name, product description, quality and duration of storage, intended use, countries of origin, packaging, and transport-specific information (symbols, means of transport, fitness for container transport etc.). At the heart of the cargo information are the risk factors, coupled with loss prevention measures. This section points up special risks which arise during transport, handling and storage and makes recommendations about loss prevention.

The risk factors are:

- Temperature
- Gases, Self-heating/Spontaneous combustion
- Mechanical influences
- Humidity/Moisture
- Toxicity
- Hazards to health
- Ventilation
- Odor
- Shrinkage/Shortage/Theft
- Biotic activity
- Contamination
- Insect infestation/Diseases

The susceptibility to risk of foodstuffs, semiluxury items and animal feedstuffs is directly related to their water content and biotic activity. The requirements relating to storage climate conditions result from these two variables .

The weak points of industrial goods lie in their sensitivity to corrosion, physical acceleration, such as oscillation, vibration, jolting, and in some cases in their chemical reactivity.

In the case of foodstuffs, semiluxury items and animal feedstuffs, the following basic rule may be deduced for assessing risk potential: the higher the water content and biotic activity of a product, the more stringent its requirements for cargo care and/or storage climate conditions. Fitness for container transport may be derived directly from consideration of the above-mentioned variables.

As far as industrial products are concerned, the greater their sensitivity to corrosion and acceleration of any kind and their chemical reactivity, the more stringent the requirements with regard to packaging, securing, shock absorption etc., if fitness for container transport is to be achieved.

14.4 Possible applications of cargo information with regard to container transport

By using the cargo information, consignor and receiver can ensure that optimum transport conditions are provided for the widest possible range of products with regard to all areas of risk.

The database may be of use to all transport professionals when putting together integrated transport chains, in particular within the container transport system.

Data evaluation also allows optimum, tolerable and harmful transport climates to be determined for transport-sensitive goods (see Fig. 66).

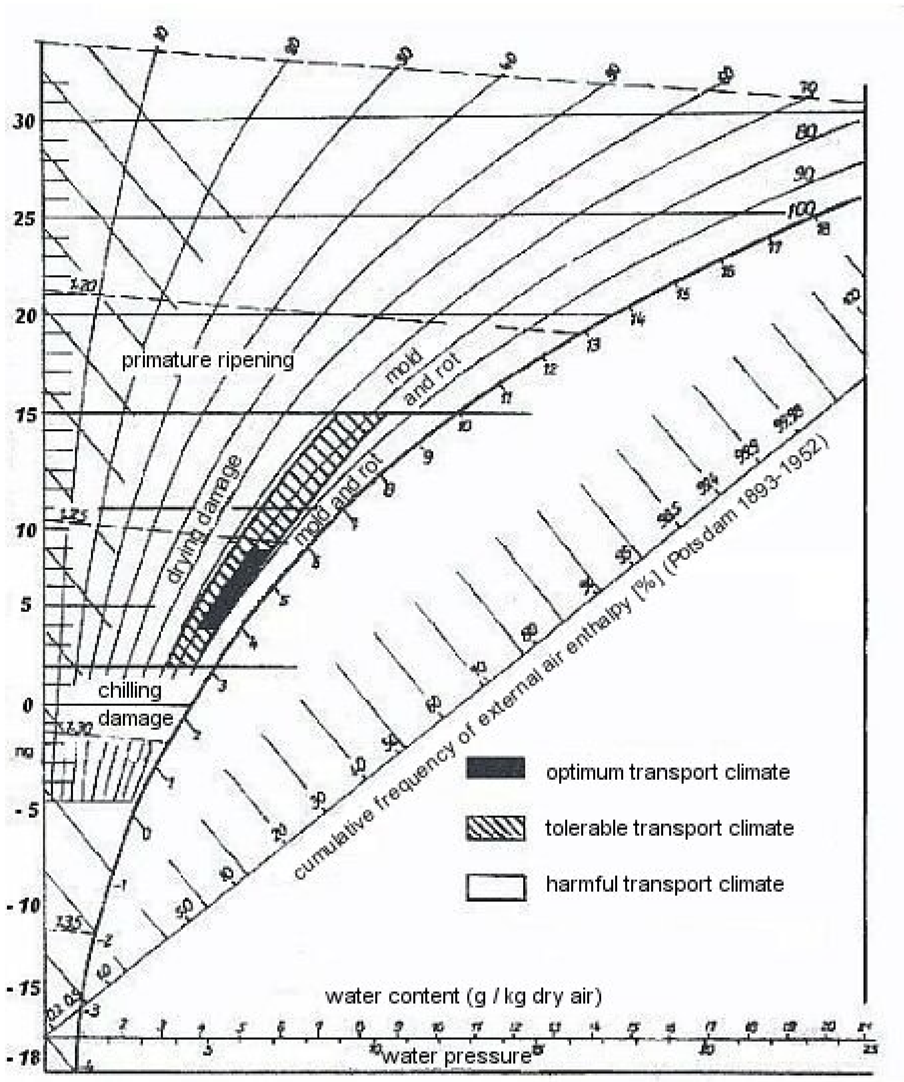


Figure 66: Optimum, tolerable and harmful transport climates for oranges

On the basis of these considerations, it is possible to derive approaches to improving the quality of the transport process, such as with regard to the instrumentation to be used for monitoring the goods in the warehouses or during packing of the containers and finally on continuation of the transport chain as far as the consumer.

Goods can be rendered fit for container transport by taking account of the individual transport information relating to loss prevention. Fitness for container transport may depend on the season or the route the cargo will take over land or sea. It must be adapted to the conditions of the transport route.

The cargo information may also be helpful when considering how best to utilize a standard container or the possible use of other container types.

The suitability for transport or fitness for container transport of a product may be assessed on the basis of a systematic approach to the goods which takes account of the necessary storage climate conditions, which are based essentially on the water content of the goods, which interacts with the humidity and temperature conditions, ventilation and concentration of harmful substances. This database may form the basis of a consultancy system,

providing a service ranging from advice for transport customers to establishing the cause in the event of cargo damage.

The consequent minimization of loss may have a very positive effect on a company's commercial and economic results and likewise on customer relations.

15 Maintaining the quality of highly perishable goods

15.1 Definition of "highly perishable"

15.1.1 "Plus" goods

15.1.2 "Minus" goods

Chilled and frozen goods are predominantly foodstuffs which have their origins in the animal or plant kingdom. Foodstuffs may rapidly lose quality at normal temperatures, overripeness, shriveling, mold, rot, loss of aroma and vitamins, rancidity and formation of toxic substances constituting typical changes which within a short time impair the enjoyment of foodstuffs or render them inedible. For this reason, they are known as highly perishable foodstuffs. Their shelf life, quality and freshness may be maintained for an extended period by applying chilling or freezing technology.

Foodstuffs are divided into three groups in accordance with the human body's nutritional requirements:

- Proteins and minerals for development and growth
- Carbohydrates and fats for energy
- Trace elements and vitamins to regulate biological processes

A feature common to highly perishable foodstuffs is their water content, which generally amounts to more than 70 -> 90% relative to the total mass of a product. Due to their high water content, these products release water vapor into the storage atmosphere. They are thus classified under water content class 3 (WCC 3).

They include vegetable products, e.g. bananas, pineapple, citrus fruit, pomaceous and stone fruit, berry fruit, vegetables, potatoes and onions, and animal products, e.g. meat, fish, eggs, fats and cheese.

In fruits and plant parts which have been separated from the parent plant, degradation processes predominate, their supply of new nutrients having been cut off.

They are therefore products displaying 2nd order biotic activity (BA).

Respiration processes have to be specifically controlled (e.g. "dormancy temperatures", and particular temperature, humidity/moisture and ventilation conditions (SC VII) are therefore required, as is intensive ventilation. This is known as temperature-controlled transport. For some plants, the provision of a controlled atmosphere (CA), SC VIII is even more favorable.

Refrigerated containers with a fresh air supply require specific cargo care, and these are known as thermally insulated refrigerated containers with a temperature-controlled atmosphere, i.e. which can be cooled or heated, or CA containers. They are wholly cut off from the external air. The shelf life of fruit and vegetables can sometimes be extended by using a controlled atmosphere, relative to normal refrigerated transport.

Meat and fish also belong to this group, but their biotic activity is only 3rd order (BA 3), so meaning that only particular temperature and humidity/moisture conditions (SC VI) are necessary and they are generally transported in refrigerated containers at subzero temperatures. To prevent weight loss, associated with drying-out of surfaces, high relative humidities are favorable.

Newer refrigerated container units have the technical capability to effect controlled moistening of the cooling air in the plus temperature range. According to practical reports, although these do not solve all the technical problems, the possibility of moistening does exist in principle. At subzero temperatures, this possibility does not exist. The humidity/moisture of the cooling air below freezing depends to a considerable extent on the temperature difference between the cooling air (return air) and the evaporators. How cold an evaporator has to be in order to cool the cooling air to a particular temperature depends in turn on its size (the smaller the evaporator surface, the lower the temperature and vice versa). Furthermore, the humidity/moisture is influenced by the quantity of evaporating, frozen water (sublimation). Since meat and fish are generally loaded in virtually water vapor-tight packaging, the amount of sublimated moisture is very slight. Evaporator sizes are predetermined at the time of construction and there is thus no possibility of influencing humidity/moisture at subzero temperatures. Since, for this reason, it is not always possible to achieve optimum humidity/moisture, it is all the more important that the goods are packaged in water vapor-tight films, for example, in order to prevent weight losses and drying-out.

15.1.1 Plus goods

Refrigerated transport should be understood to mean the transportation of perishable goods in refrigerated containers in a fully air-conditioned atmosphere, in which the desired transport temperature is achieved by means of refrigeration units.

Chilled goods may be subdivided into plus goods (chilled goods in the narrower sense) and minus goods (frozen goods) (see Fig. 67).

Plus goods are stored at temperatures above 0°C in the product-specific temperature range, so as on the one hand to reduce biotic processes, above all respiration, and on the other hand to prevent chilling damage (chilling). Plus goods include fruit, vegetables and seed stock and propagation materials. Fruit and vegetables are living organisms in which respiration processes predominate due to separation from the parent plant. Plus goods are generally loaded into the containers after appropriate pre-chilling.

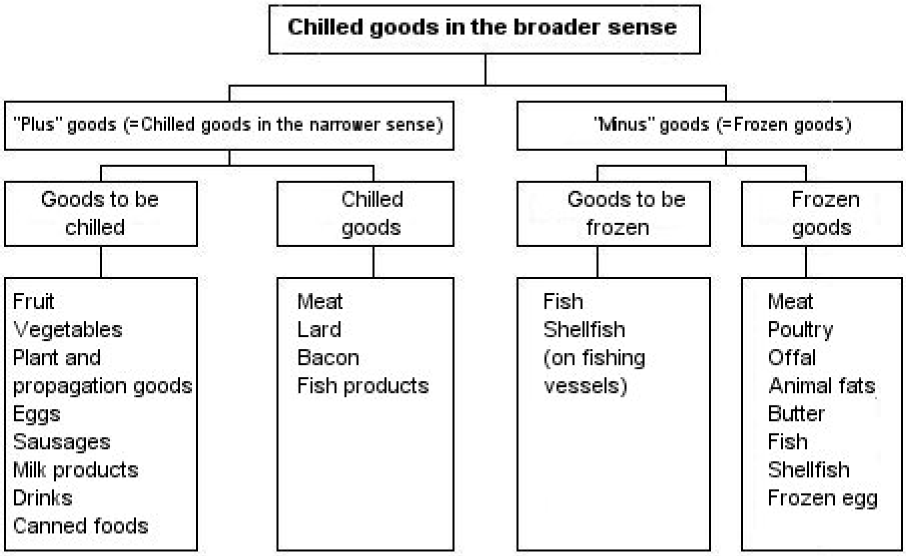


Figure 67: Classification of chilled goods

15.1.2 Minus goods

Minus goods or frozen goods are packed into the container frozen and have in general to be kept at temperatures of from -18°C to -27°C. They include meat, fish, fats and derived products, these being goods in which respiration processes are suspended ("lifeless goods") but which do still undergo biochemical and microbial degradation processes, which may lead rapidly to spoilage. In recent years, a particular "niche business" using low temperature refrigerated containers or deep freeze reefer containers has developed, but so far it is limited almost exclusively to the Japanese market. These containers are used in particular to transport tuna and derived products at -60°C.

On fishing vessels, fish and shellfish are frozen as soon as they are caught.

The purpose of chilling and freezing is to maintain the quality of the goods during transport, the idea being that, after transport, chilled meat will be of the same quality as fresh meat. However, in the case of fruit, e.g. bananas, it may be necessary to allow certain ripening processes to proceed, albeit at greatly reduced rate, so enabling the fruit subsequently to ripen fully in ripening warehouses. This boils down to maintaining particular properties of the product, which determine its market value. This objective cannot be achieved merely by specifying certain technical control parameters, but also requires a raft of other cargo care measures, which may differ greatly from one product to another.

15.2 Causes of spoilage of organic goods

Changes in the quality of organic goods with a high water content, which include a large number of foodstuffs, may be caused by five factors:

- Infestation with microorganisms (mold and rot)
- Biochemical changes, in particular respiration and ripening processes
- Physical changes, in particular in the form of drying-out (shriveling, weight loss)
- Chilling damage and frost damage
- Postharvest diseases
- Mechanical damage during handling and transport

These factors frequently interact with one another.

15.2.1 Microbiological causes of spoilage

Layers of mold and areas of rot are caused by the activity of microorganisms, primarily including fungal molds, yeast and bacteria. When accompanied by a high water content, foodstuffs form an ideal nutrient medium for microbes, which break down carbohydrates, proteins and fats with the assistance of enzymes so impairing quality, consistency and edibility.

Microbes are microscopically small living organisms. The small size of the cells, which have a very large surface area relative to their mass, results in lively metabolic activity, so leading to rapid cell enlargement and multiplication and a high level of cell respiration. They are capable of surviving unfavorable living conditions (e.g. unfavorable temperatures) by forming spores. If living conditions then become favorable again, they germinate. Thus, for example, if a container has not been carefully cleaned, goods may subsequently become infected with spores from previous cargoes which resume activity in the new environment (secondary infection). This is why refrigerated containers must be in a thoroughly hygienic condition.

Fungal molds form hyphae. i.e. branched fungal filaments, which are visible as an absorbent cotton-like covering (mycelium) and break up the surface of the substrate or make it slimy. The actual layer of mold is formed by the conidiophores, which produce the spores (conidia). The development of fungal molds is divided into four phases, damage to goods occurring in the third and fourth phases:

1st phase	-	Germination of an unbranched mycelium fiber (Fig. 68)
2nd phase	-	Formation of the original mycelium, which grows and forms four to five hyphae (Fig. 69)
3rd phase	-	Developed mycelium with numerous hyphae and a number of fruiting bodies (Fig. 70, Fig. 74)
4th phase	-	Reproductive stage with very dense mycelium layers and numerous conidiophores with spores (Fig. 71, Fig. 75).

Figure 68:
Stage I of mycelial growth

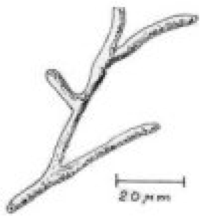


Figure 69:
Stage II of mycelial growth

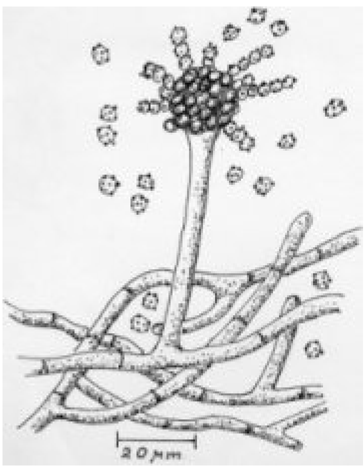


Figure 70:
Stage III of mycelial growth

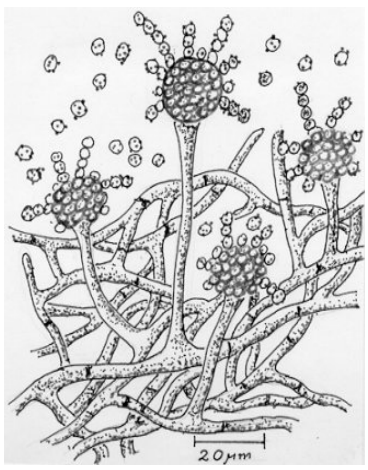
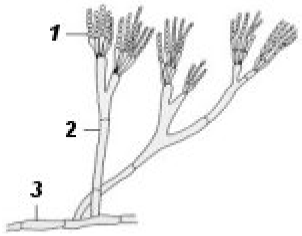


Figure 71:
Stage IV of mycelial growth



1 - Conidia
2 - Conidiophore
3 - Mycelial filament

Figure 72:
Penicillin mold
(Penicillium italicum) [29]

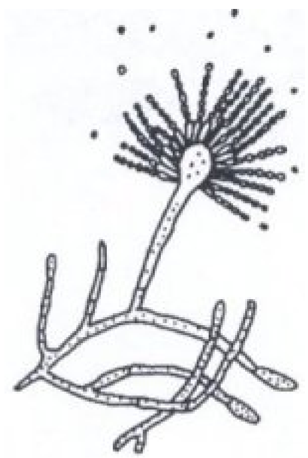


Figure 73:
Aspergillus flavus
[34]

Figs. 72 and 73 show two important examples of fungal molds, penicillin mold (Penicillium italicum) and Aspergillus flavus; the latter forms aflatoxin which is one of the most potent cytotoxins which has yet been discovered.

Figure 74: Lemon, suffering from green mold - stage III (white) and stage IV (green)

Figure 75: Blue mold caused by the fungal mold Penicillium italicum, stage III (white) and stage IV (blue), on an orange. Spores can be seen at the top.

Fig. 76 shows fresh ginger, which began to go moldy (white) and to sprout (green) in a refrigerated container because the temperature and humidity were too high.

Figure 76: Fresh ginger, which began to go moldy (white) and to sprout (green) in a refrigerated container because the temperature and humidity were too high

15.2.2 Living conditions of microorganisms

15.2.2.1 Temperature requirements

As far as the temperature requirements of microorganisms are concerned, it is possible to distinguish between three groups of "living temperatures", at which metabolic and multiplication activities proceed, as do spoilage processes in foodstuffs:

- types that thrive at low temperatures (psychrophilic),
- types that thrive at medium temperatures (mesophilic)
- types that thrive at high temperatures (thermophilic), (see Table 4 and Fig. 77)

Group	Minimum (°C)	Optimum (°C)	Maximum (°C)
Cryophilic or psychrophilic microorganisms	-10 - 0	15 - 20	20 - 30
Mesophilic microorganisms	10 - 30	20 - 37	35 - 50
Thermophilic microorganisms	25 - 50	50 - 65	60 - 95

Table 4: Classification of microorganisms by temperature group

The optimum temperature is the temperature at which the highest level of multiplication occurs, while the minimum and maximum temperatures represent the lower and upper multiplication limits respectively. However, spores may survive at much higher and lower temperatures.

The most important rot and fermentation pathogens are mesophilic microorganisms. The minimum temperature shows clearly that metabolic activity can be restricted by refrigeration.

Also of relevance to the cargo care of chilled goods are psychrophilic microorganisms, whose minimum temperature may be as low as -10°C (yeasts, molds, bacteria), so meaning that they may still remain active in chilled storage. These may cause secondary infection of chilled goods in refrigerated containers which have not been carefully cleaned.

Molds generally belong to the mesophilic temperature group; however, some types do also thrive on frozen fish and water-containing fats down to temperatures as low as -10°C.

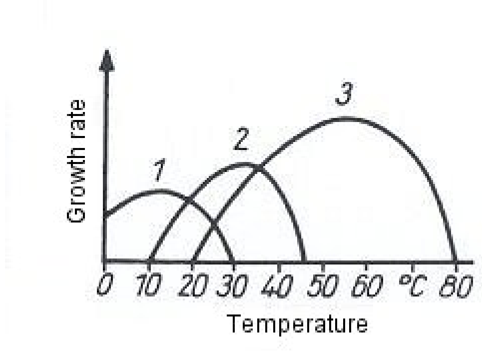


Figure 77: Dependency of bacterial growth on temperature [57]

1 Cryophilic (psychrophilic) types
2 Mesophilic types
3 Thermophilic types

15.2.2.2 Humidity/moisture requirements

The nutrients are absorbed by the microorganisms after having been dissolved by means of enzymes. Molds are divided into three groups (see Fig. 78):

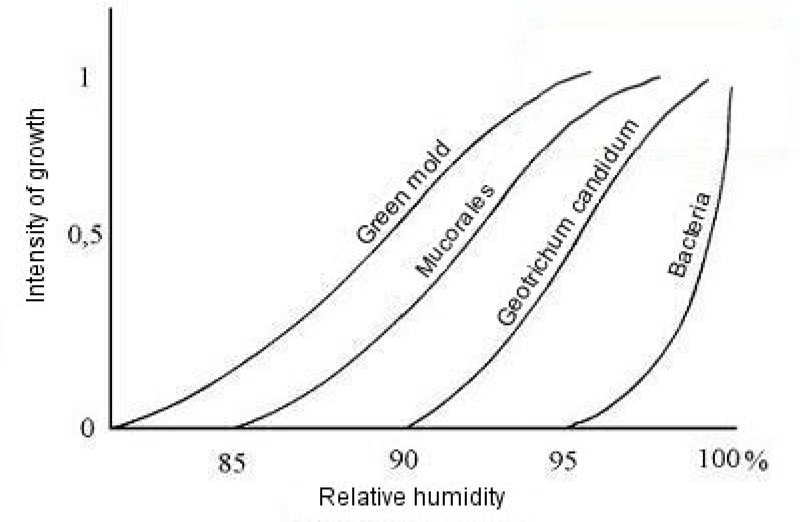


Figure 78:
Intensity of microbial growth as a function of relative humidity;
Hermann [17]

1. Types surviving at low relative humidities of approx. 75% (xerophilic), such as green mold
2. Types thriving at relative humidities of over 86% (mesophilic), such as Mucorales fungi
3. Types requiring a relative humidity of over 90% (hygrophilic), such as Geotrichum candidum.
4. Bacteria are active above 95% relative humidity.

Overall, the mold growth threshold should be deemed to stand at 75% relative humidity, while bacteria only become active above 95%. This explains why fruit firstly suffers mold attack, with bacterial decomposition processes only starting at a higher relative humidity resulting, among other things, from the associated higher level of respiration.

15.2.2.3 Atmospheric oxygen requirements

As far as the atmospheric oxygen requirements of microorganisms are concerned, it is possible to distinguish between three groups:

1. Types which absolutely have to have atmospheric oxygen to live (obligate aerobe)
2. Types which thrive only in the absence of atmospheric oxygen (obligate anaerobe)
3. Types which live in both the presence and absence of oxygen (facultative anaerobe)

Molds are generally typical aerobes, meaning that as a rule they colonize the surface of the goods (see Figs. 74 and 75). Controlled atmosphere storage, e.g. of apples, is an effective method of inhibiting aerobes. On the other hand, a large number of rot pathogens are anaerobes, capable of causing damage to preserved foods, for example.

Figure 74: Lemon, suffering from green mold - stage III (white) and stage IV (green)

Figure 75: Blue mold caused by the fungal mold Penicillium italicum, stage III (white) and stage IV (blue), on an orange.
Spores can be seen at the top.

15.2.2.4 pH value

The pH value describes the hydrogen ion concentration, i.e. how acidic or alkaline a liquid is. Pure water has a pH value of 7. It is not so much a question of how much acid is present, but more of its concentration. Acidic solutions are < 7, alkaline solutions are > 7; the more acidic the chilled goods, the lower the pH value, the more alkaline, the higher the pH value. If the pH value is lower than 4, only yeast and mold are capable of any activity; between 4 and 6, it is carbohydrate-degrading bacteria in particular which may be found to be active; at a pH value of between 6 and 8, protein-decomposing bacteria (rot bacteria) and mold develop, in particular.

Some examples of pH values:

- Lemons 2.0
- Tomatoes 4.3
- Cows' milk between 6.5 and 7

15.2.3 Biochemical causes of spoilage

15.2.3.1 Enzymatic action

Many foodstuffs, such as fruit, vegetables, meat and fish, contain enzymes, which have a catalytic action and break down nutrients. Like microorganisms, enzymes are also dependent to a considerable extent on the temperature and water content of the goods.

The optimum temperature for enzymatic activity is 45°C. Lower temperatures slow down activity; however, activity is possible at far lower minus temperatures than is the case with microorganisms. Most enzymes are not inactivated until a temperature as low as -20 to -30°C is reached. Frozen goods therefore have only a limited storage life: if stored for many months, enzymatic processes may cause undesired changes and finally lead to spoilage.

Enzymatic activity is also associated with water: enzymes only become active when they are in the form of swollen proteins. Table 5 shows the activity of enzymes and microorganisms as a function of temperature.

<table>
<tr><th>°C</th><th>Enzymes which affect flavor and structure</th><th>Microorganisms which cause mold growth</th><th>Microorganisms which cause food poisoning</th></tr>
<tr><td>20</td><td rowspan="8">high level of activity</td><td rowspan="5">rapid development</td><td rowspan="4">rapid development</td></tr>
<tr><td>15</td></tr>
<tr><td>10</td></tr>
<tr><td>5</td></tr>
<tr><td>0</td><td>slow development</td></tr>
<tr><td>- 5</td><td>slow development</td><td rowspan="7">inactive</td></tr>
<tr><td>- 10</td><td rowspan="6">inactive</td></tr>
<tr><td>- 15</td></tr>
<tr><td>- 20</td><td rowspan="4">low level of activity</td></tr>
<tr><td>- 25</td></tr>
<tr><td>- 30</td></tr>
<tr><td>- 35</td></tr>
</table>

Table 5: Activity of enzymes and microorganisms as a function of temperature; taken from Alders [2]

15.2.3.2 Respiration of goods of vegetable origin

Aerobic respiration:
Untreated fruit and vegetables are living organisms in which metabolic processes continue after harvest. The most important metabolic process is respiration, during which oxygen is absorbed from the air and carbon dioxide, water vapor and heat are excreted.

This proceeds according to the equation:

$C_6H_{12}O_6 + 6\ O_2 => 6\ CO_2 + 6\ H_2O + 2{,}826$ kJ

These products of respiration have to be removed from the container by ventilation. The heat which is released (see kJ in the equation) is known as heat of respiration. The respiration intensity of goods of vegetable origin is dependent on the type, quality and degree of ripeness of the fruit, storage temperature, water content and air composition.

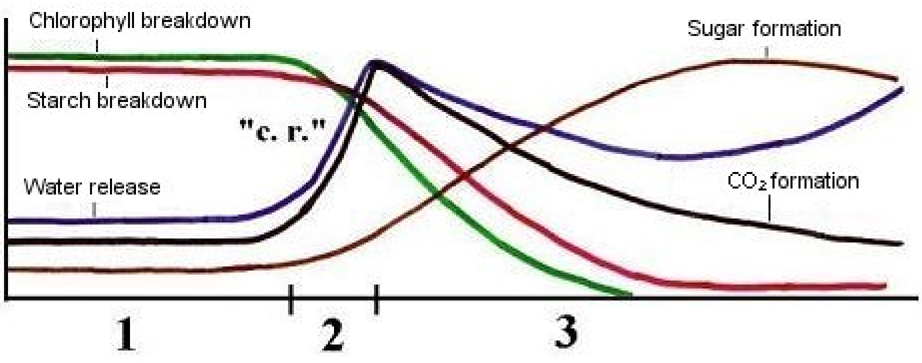


Figure 79: Ripening of bananas

1 - preclimacteric (green)
2 - climacteric (turners)
3 - postclimacteric (yellow)
"c.r." - "climacteric rise"

According to Fig. 79, the respiration intensity of bananas, for example, starts at a minimum level, then increases rapidly and intensively to a maximum, after which it drops until the bananas die of old age. This last increase in carbon dioxide excretion, known as the "climacteric rise", marks the beginning of maturation of the fruit.

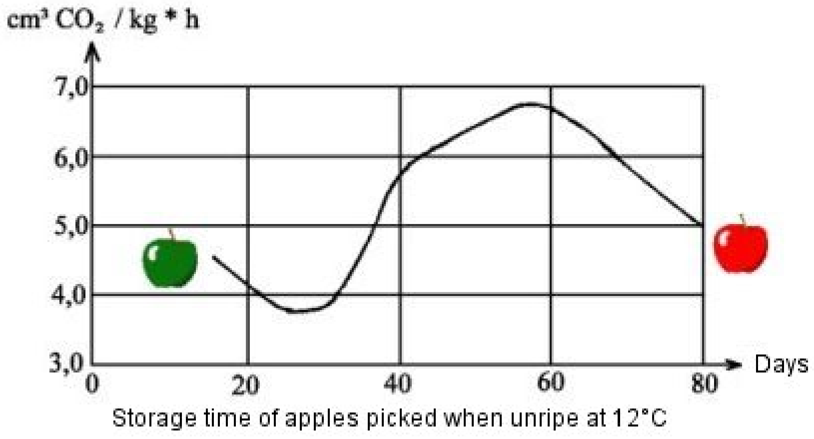


Figure 80: Respiration curve for ripening apples [29]

Fig. 80 shows a respiration curve for ripening applies, which likewise starts at a minimum, then rises rapidly to a maximum, which, as here, may sometimes be twice the minimum, after which it falls away. The heat evolved by the fruit is known as respiration heat. When transporting fruit in a refrigerated container, it is essential to chill it as quickly as possible by heat extraction, so as to reduce the evolution of respiration heat.

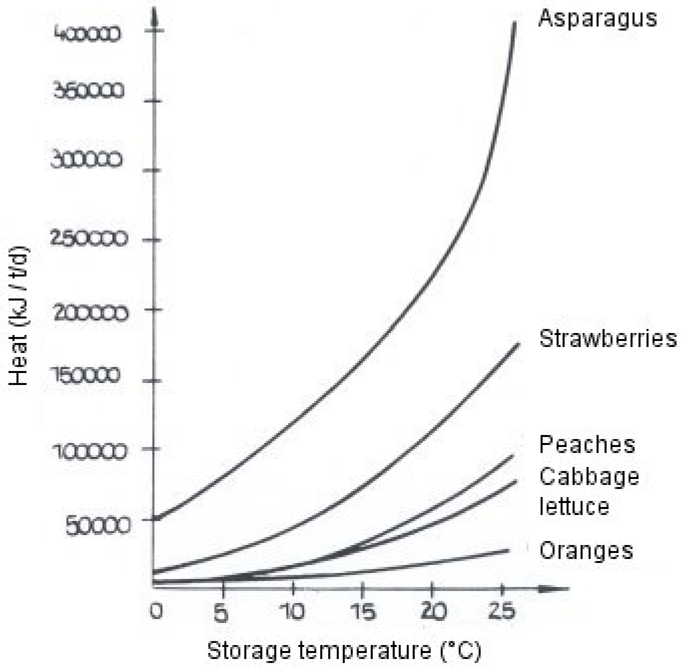


Figure 81: Respiration heat produced by fruit and vegetables [1]

Evolution of heat is particularly temperature-dependent (see Fig. 81): the higher is the temperature, the more intensive is respiration and the greater is the amount of heat released. Chilling is the most effective method of limiting respiration intensity and thus nutrient loss.

Respiration intensity generally reduces to between half and a third when the temperature is lowered by 10°C , i.e. the storage life can be doubled or even trebled by lowering the temperature by 10°C (see Arrhenius equation).

Anaerobic respiration (alcoholic fermentation):
If the refrigeration fails or ventilation is poor, respiration intensity may fall to 12 vol.% due to a drop in oxygen content and rise in carbon dioxide content of the ambient air, thereby resulting in a risk of anaerobic respiration, leading to the end products ethanol and carbon dioxide:

$C_6H_{12}O_6$ => 2 C_2H_5OH + 2 CO_2 + 117.2 kJ

Fermentation products may cause an entire container cargo of citrus fruits, for example, to begin fermentation within just a few hours. When a refrigerated container containing goods of vegetable origin is opened, there is not as a rule any danger of asphyxiation due to the build up of carbon dioxide or to oxygen consumption, since the CO_2 (gas), which is heavier than air immediately "flows out" of the container "like water" when the container doors are opened. The space left by it fills up with ambient air, so that there is no danger when entering the container.

15.2.3.3 Ripening of goods of vegetable origin

When vegetable, primarily fruit, products ripen, they pass through three ripening stages (see also Fig. 79):

1. Picking, harvesting, shipping or industrial ripeness (preclimacteric)
   Most fruit commences transport at the picking ripeness stage, e.g. autumn and winter varieties of pomaceous fruit, citrus fruit, bananas, pineapple and tomatoes. At this stage the fruit has a hard consistency and a green color. The high starch, pectin, acid and tannin content gives it a sharp, acidic, often astringent (mouth-puckering) taste.

2. Ready-to-eat or ripe for consumption (climacteric)
   The biochemical processes lead to the conversion of starch into sugar, such that the ripe fruit develops its typical sourish sweet aroma, together with a soft consistency and a species-specific color. The optimum chemical composition and thus the maximum nutritional value are achieved.

3. Physiological ripeness (postclimacteric)
   Decomposition processes lead to a type of autolysis (self-digestion): the flesh of the fruit becomes mealy and pasty and the flavor becomes insipid. Overripe fruit easily falls victim to mold and bacteria.

   This stage is already considered overripe by the consumer.
   Vegetables are generally harvested at maximum ripeness. This means that they do not undergo any quality-improving ripening during subsequent storage, making vegetables products which do not store well and are unsuited to transport over long distances.

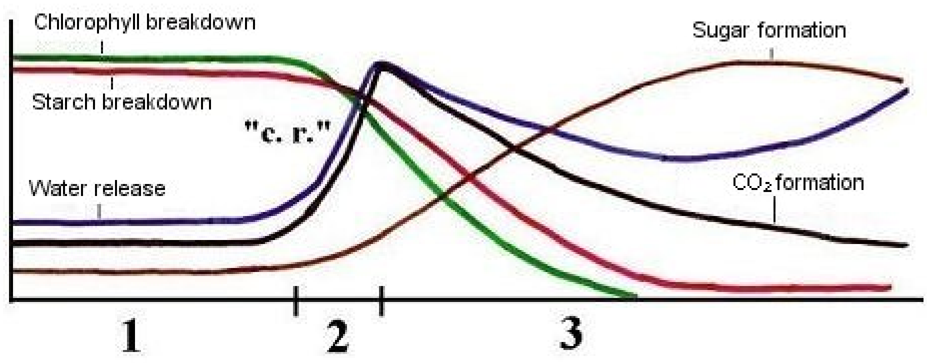


Figure 79: Ripening of bananas

1 - preclimacteric (green)
2 - climacteric (turners)
3 - postclimacteric (yellow)
"c.r." - "climacteric rise"

15.2.3.4 Allelopathy

Allelopathy is understood to mean the mutual influence exerted by goods of vegetable origin through the gases they give off, which have an effect on metabolism. In this way, in ripening fruit in particular traces of ethylene (C_2H_4) are formed and pleasant-smelling aromatic substances are formed and released. Since respiration is at its most intensive in the climacteric, a particularly large amount of ethylene is produced in addition to carbon dioxide and may cause fruit nearby to ripen more quickly. A concentration of 0.02% of ethylene in air accelerates the ripening process by 4 - 10 times. Ethylene-producing goods of vegetable origin are divided into five groups (see Table 6 and Fig. 82).

Ethylene production rate [µl/(kg*h)]	**Products**
Zero: 0	Chinese artichoke, Japanese radish, prickly pear, Florence fennel, cassava, pak-choi cabbage, cranberry, black salsify
Very low: 0.01 - 0.1	Pineapple, artichoke, cauliflower, broccoli, watercress, mushroom, chicory, Chinese cabbage, date, endive, pea, Jerusalem artichoke, grapefruit, curly kale, ginger, carrot, potato, cherry,

	garlic, celeriac, kohlrabi, lime, sweetcorn, mandarin, horseradish, orange, parsnip, parsley root, chanterelle, leek, radish, rhubarb, Brussels sprout, beetroot, red cabbage, turnip, green cabbage, asparagus, spinach, rutabaga, celery, sweet potato, tangerine, taro, grape, white cabbage, lemon, onion
Low: 0.1 - 1.0	Winter cherry, aubergine, egg-plant, berries, bitter squirting cucumber, Seville orange, bean, clementine, persimmon, iceberg lettuce, baby sweetcorn, pomegranate, guava, cucumber, starfruit, kiwifruit, coconut, cabbage lettuce, kumquat, pumpkin, limequat, olive, sweet pepper, chili pepper, quince, garden radish, satsuma, watermelon, courgette, zucchini
Moderate: 1.0 - 10.0	Banana, fig, feijoa, honeydew melon, Jack fruit, lychee, mango, mangosteen, plum, tomato
High: 10.0 - 100.0	Apricot, avocado, tamarillo, pear, papaya, peach/nectarine
Very high: > 100.0	Apple, cherimoya, passion fruit

Table 6: Ethylene production of various types of fruit and vegetables;
taken from Alders (with additions) [2]

Fruits may be divided into two categories on the basis of their respiration profile: "climacteric fruits" and "non-climacteric fruits", (see Table 7).

Climacteric fruits	**Non-climacteric fruits**
Apples	Pineapple
Apricots	Blueberries
Avocados	Strawberries
Bananas	Cucumbers
Pears	Limes
Figs	Oranges
Kiwifruit	Satsumas/mandarins
Mangoes	Grapes
Papaya	Lemons
Passion fruit	
Peaches	
Plums	
Tomatoes	

Table 7: Classification of goods of vegetable origin by respiration behavior
during ripening; taken from Alders [2]

Climacteric fruits display the typical respiration profile, as illustrated in Fig. 79 using bananas as an example, which is associated with high levels of carbon dioxide and ethylene production during ripening. Non-climacteric fruits, e.g. potatoes, root vegetables, strawberries, do not display the increase in respiration rate known as the "climacteric rise"; instead, the respiration rate falls during ripening, with only small amounts of ethylene consequently being produced.

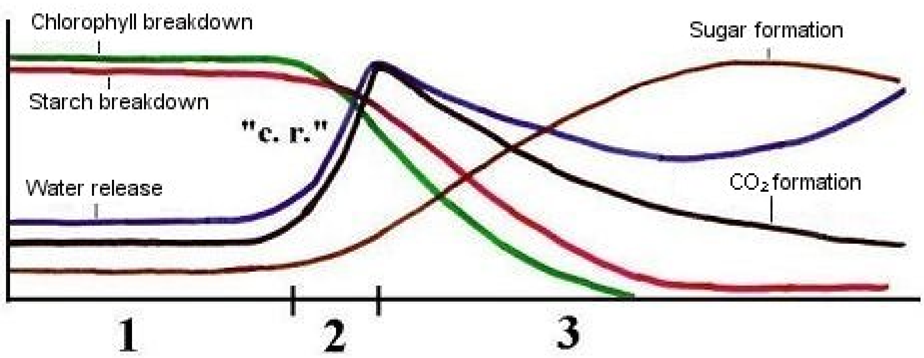


Figure 79: Ripening of bananas

1 - preclimacteric (green)
2 - climacteric (turners)
3 - postclimacteric (yellow)
"c.r." - "climacteric rise"

When transporting fruit of a single type by container, it must be ensured that the transportable unripe fruit at the preclimacteric stage is not stowed together with fruit in an advanced state of ripeness, because the ethylene released by the ripening fruit causes the unripe fruit to ripen prematurely. If one item of fruit begins to excrete ethylene, a whole container cargo may begin the increase in respiration associated with the climacteric (see turners in cargoes of bananas).

If an on-board porthole system is used, all the fruit in all the containers with which it is connected may then suffer premature ripening, which may amount to as many as 100 metric tons of bananas, for example.

In addition to the increase in respiration, ethylene initiates other normal ripening processes, such as chlorophyll degradation, starch hydrolysis and sugar build-up.

When fruit and vegetables of various types are being transported by container, care must be taken to ensure that the types of fruit and vegetables belong to different categories of ethylene producer, as shown in Table 6 and Fig. 82. Thus, for example, apples, which produce large quantities of ethylene, cause potatoes to germinate prematurely. Cucumbers turn yellow on exposure to ethylene from apples or tomatoes. Table 8 shows the ethylene sensitivity of various types of fruit and vegetables.

Ethylene sensitivity	Products
Zero	Seville orange, Chinese artichoke, clementine, fennel, kumquat, pak-choi cabbage, chanterelle, cranberry, garden radish, satsuma
Low	Pineapple, winter cherry, artichoke, aubergine, egg-plant, berries, bitter squirting cucumber, date, Jerusalem artichoke, fig, feijoa, baby sweetcorn, pomegranate, ginger, prickly pear, starfruit, carrot, cherry, garlic, celeriac, coconut, pumpkin, sweetcorn, cassava, horseradish, sweet pepper, parsnip, chili pepper, parsley root, radish, rhubarb, beetroot, turnip, black salsify, rutabaga, sweet potato, taro, grape, watermelon, onion (dry)
Moderate	Tamarillo, bean, mushroom, endive, pea, Jack fruit, grapefruit, guava, potato, cabbage lettuce, lime, lychee, mandarin, olive, orange, leek, asparagus, celery, tangerine, lemon, courgette, zucchini, onion (green)
High	Apple, apricot, avocado, banana, pear, cauliflower, broccoli, watercress, cherimoya, chicory, Chinese cabbage, persimmon, iceberg lettuce, curly kale, cucumber, honeydew melon, kiwifruit, mango, mangosteen, papaya, passion fruit, peach, plum, quince, Brussels sprout, red cabbage, spinach, tomato, white cabbage, savoy cabbage

Table 8: Ethylene sensitivity of various types of fruit and vegetables;
taken from Alders (with additions) [2]

In practice, ethylene formation is prevented to a considerable extent by a specific dormancy temperature together with reduced respiratory activity (see Section 15.2.4.2). On the other hand, this effect may be used to advantage in ripening warehouses to bring about ripening at the desired time by exposure to ethylene.
Measurement of ethylene concentration may be performed using an ethylene monitor (see TIS).

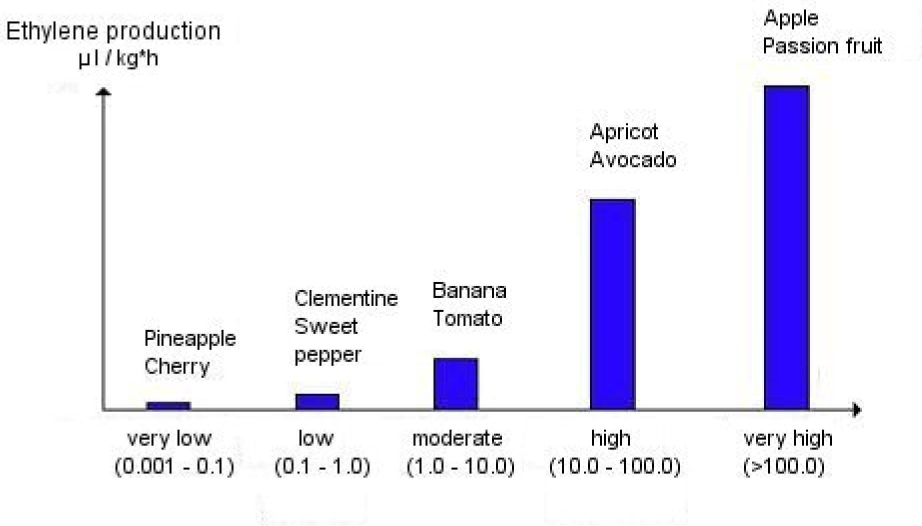


Figure 82: Ethylene production of fruit and vegetables

15.2.4 Physical causes of spoilage

15.2.4.1 Drying-out of chilled & frozen goods

Owing to the high water content of highly perishable goods, a vapor pressure gradient arises between the surface of a cargo and the ambient air, resulting in high relative humidities, which have to be maintained in order to prevent excessive evaporation of water vapor or ice formation (sublimation) at the unprotected surfaces.

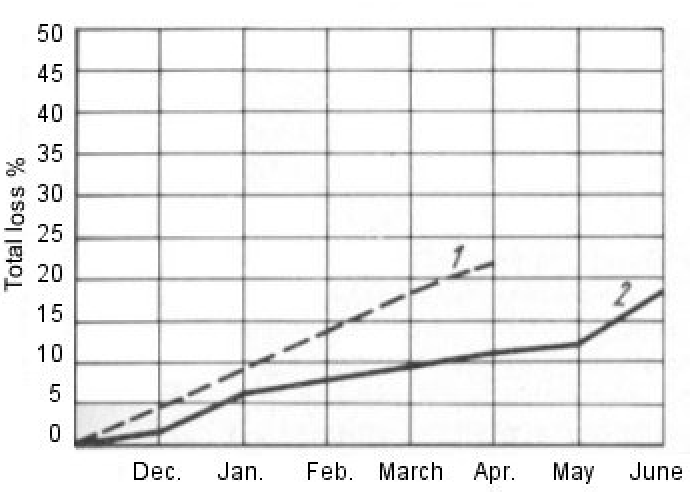
In general, therefore, an optimum humidity range of 85 - 90% is recommended for the refrigerated transport and fruit and vegetables while a value of up to 95% is recommended for frozen meat.

Although low humidities inhibit the activity of microorganisms, weight losses (shrinkage/shortage) soon occur as a result of drying out, these being known as transpiration losses (evaporation losses) in the case of goods of vegetable origin. Such goods can no longer replace the water lost by transpiration, the inner pressure in the cells (turgor) falls and the goods shrivel and consequently suffer losses of weight and vitamin content.

The degree to which the goods dry out is dependent on three factors: relative humidity, temperature and air movement.

Drying-out and weight losses are the greater, the lower is the relative humidity of the refrigerated container; storage temperature is the decisive factor: at identical relative humidity, a product dries out more slowly, the lower the container temperature. Chilling and freezing temperatures reduce shrinkage/shortage. Fig. 83 compares the weight losses in apples when chilled and stored at normal temperatures. However, even at relative humidities of 90%, if a small partial pressure gradient exists between the surface of the frozen cargo and the ambient air the marginal layers of unpackaged goods can dry out considerably; in extreme cases, meat, for example, may suffer freezer burn, so called because of the associated sharply defined, dried-up, light grey/yellowish areas.

Even after thawing, the dried-out cargo remains strawy and dry, the damage being irreversible. In the case of packaged goods, drying out may occur within the package (in-package desiccation) if there are cavities and temperature differences between the product and the packaging.



1 Storage at normal temperatures   2 Chilled storage

Figure 83: Weight loss in apples (Clivia variety) when stored at normal temperatures and chilled [29]

15.2.4.2 Chilling damage and frost damage

Chilling temperatures have to be complied with precisely for goods of vegetable origin, in order to prevent chilling damage, which arises when fruit is exposed to low temperatures above freezing point. Chilling must be designed to allow metabolic processes to continue without substantial deviations from the normal metabolic profile. For example, potatoes stored < 3°C become sweet.

The fruit adopts a dormant state resulting in only slight losses in weight, nutrients and vitamins due to the reduction in respiration. It should not be assumed that the lower the temperature at which fruit is stored, the longer it will keep. Each type of fruit has a specific "dormancy temperature", which has to be complied with exactly.

These temperatures are often a long way above freezing point, e.g. 4°C in the case of apples (their freezing point is -1.4 to -2.8°C), 13-14°C in the case of bananas, 8-10°C in the case of grapefruit (see www.tis-gdv.de/Cargo information).

If the temperature falls below the dormancy temperature, the fruit may lose its ability to ripen, i.e. green fruits, e.g. tomatoes or bananas, can no longer be caused to ripen to eating ripeness even in ripening rooms kept at 15-20°C, since the metabolic processes can no longer be set in motion. They thus lose all their utility value and remain hard and green, taste turnipy and have no aroma.

Other typical manifestations of chilling damage are, for example, storage scald in apples, plums and citrus fruit, brown heart in apples (see Fig. 84), internal breakdown (soggy breakdown) especially in pomaceous fruit, wooliness in peaches.

Fruit and vegetables with a high water content freeze at temperatures < 0°C. The greater the content of substances such as mineral salts, carbohydrates etc. dissolved in the cytosol, the lower the freezing point. Thus, for example, the freezing point of oranges is -1 to -1.2°C, while that of lemons is -1.1 to 1.5°C and that of pears is -1.5 to -3.2°C.

Figure 84: Brown heart in apple;
Photo: U. Schieder

The ice crystals which arise on freezing cause mechanical damage to the cell walls and protoplasm. Cell death due to freezing results from coagulation of the protoplasm caused by dehydration and the associated increase in cytosol

15.3 Temperature-controlled container transport

15.3.1 Types of refrigerated container

Special technological solutions have been developed for transporting chilled goods in containers. Since, in container transport, the goods remain in the container from the manufacturer to the consumer, uninterrupted refrigeration must be provided.

20' and 40' containers are the most common and comprise insulated containers which are refrigerated by either an internal or an external system.

15.3.1.1 Porthole containers

Porthole containers do not have an integral refrigeration unit. They operate using the Conair system, in which the insulated containers are accommodated in specific slots on board ship and an entire stack is supplied with cold air from a single refrigeration duct via connection ports or portholes (see Fig. 85).

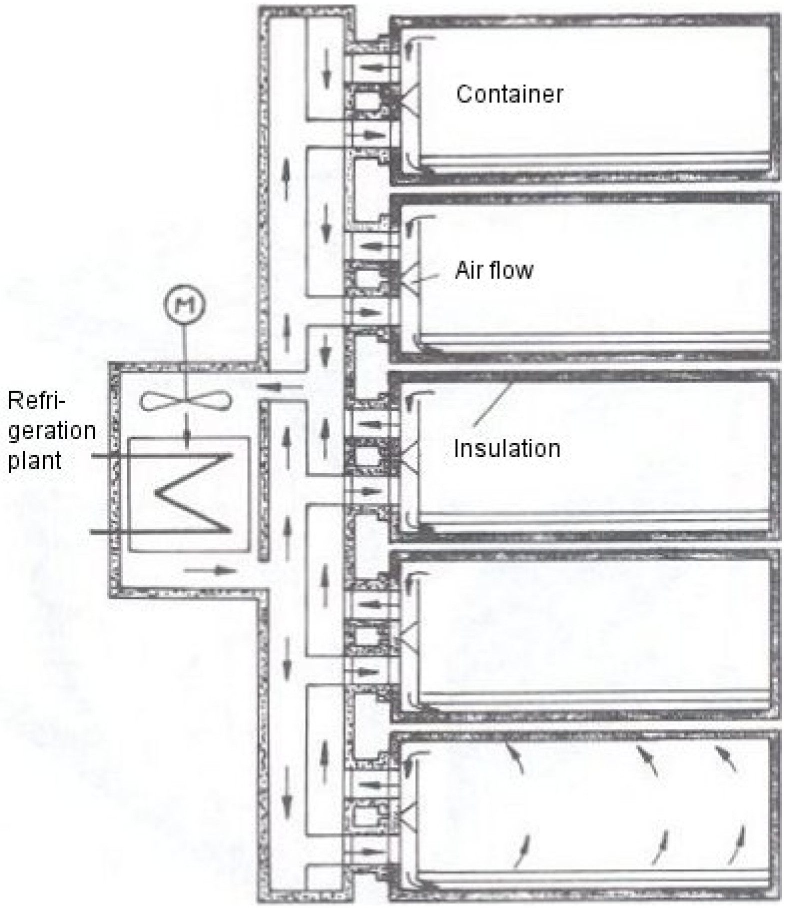


Figure 85: Air flow in Conair refrigeration duct for porthole containers

Cold air is blown in at the bottom and the "warm" air is removed at the top (see Fig. 86).

In port or during transport ashore, these containers must continue to be cooled via these refrigeration portholes. External refrigeration may also be provided by clip-on units (mobile refrigeration units which can be attached to the container).

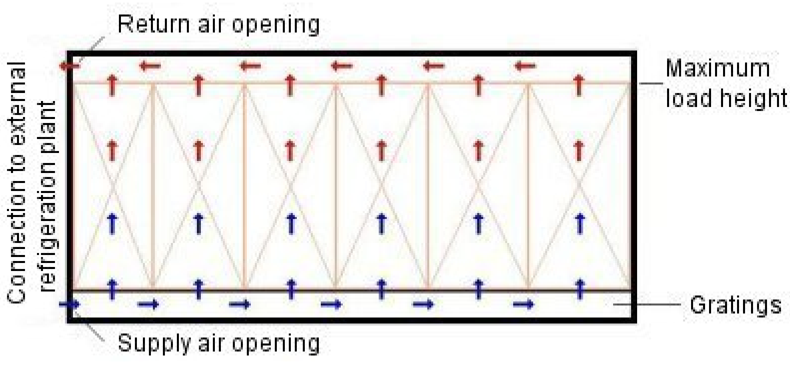


Figure 86: Air flow in a porthole container

The cold air is blown into the lower, supply air opening via the attached refrigeration unit (ship's refrigeration system, "clip-on unit" or terminal refrigeration system). It is distributed over the entire container length via the gratings and rises upwards through the cargo.

The air is then drawn off from the container's upper return air opening via the air channel left clear beneath the container roof and cooled in the attached refrigeration unit. If the maximum load height is exceeded, there is not enough space left for the air to circulate properly.

15.3.1.2 Integral Unit (Integrated Unit):

Containers having their own integral refrigeration unit are thus more widely used. These integral units are connected to the on-board power supply system (Fig. 87). All that they require is a slot with a suitable electricity supply.

Such a supply can easily be provided on ocean-going vessels, in port, at terminals and in the shipper's and receiver's warehouses. Clip-on units may additionally be fitted to many container types, in which case they serve only to supply the refrigeration unit with electricity.

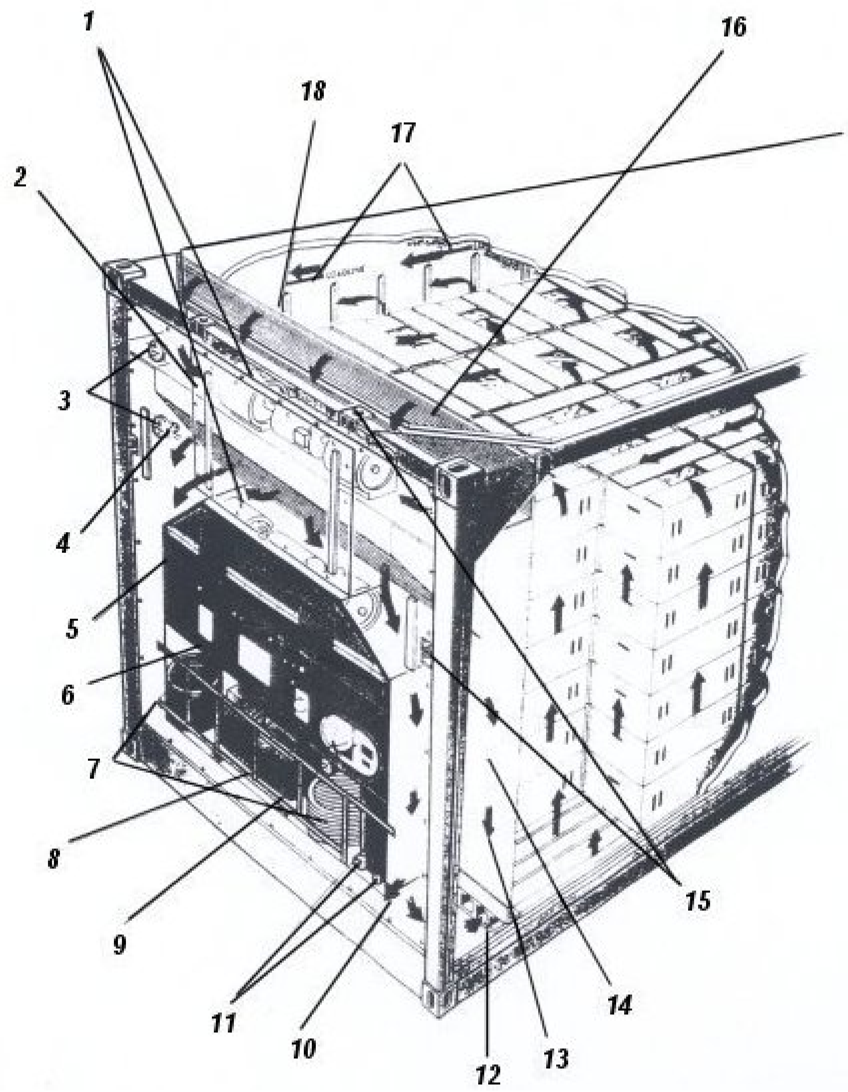


Figure 87: Air flow in a Seacold integral container

1 - Evaporator/condenser centrifugal fans with motor
2 - Evaporator section front face inspection panel
3 - Air supply and exhaust vents
4 - Air sampling or gas measurement port
5 - Condenser section drop down door
6 - Electrical compartment
7 - High and low power electrical supply cables
8 - Compressor
9 - Control compartment
10 - Supply air plenum chamber
11 - Water-cooled condenser and connection port
12 - Strengthened T-section floor to allow air flow
13 - Air extracted from the interior flows over the cooling surfaces and down the side of the container in order to achieve symmetrical air flow through the T-beam floor and the cargo.
14 - Air supply duct
15 - Diesel generator set locating points
16 - High level return air grille
17 - Loadline markings

18 - Steel inner linings for side walls

The most commonly used type of refrigerated container has an integral refrigeration unit (integral unit container). Air flow in the integral unit container is the same as that in the porthole container (see Fig. 88).

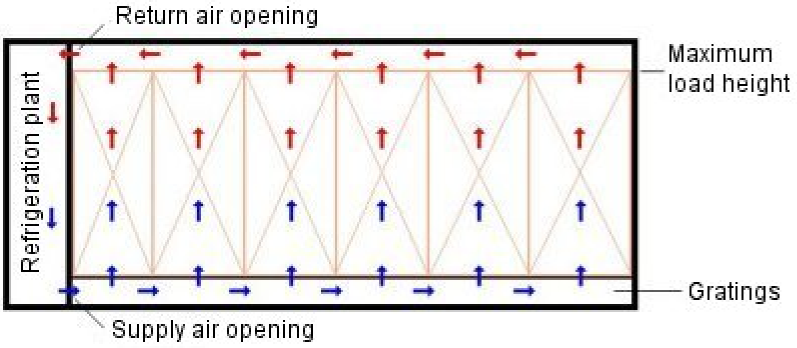


Figure 88: Air flow in integral unit container
The refrigeration unit blows the cold air into the lower part of the container. It is distributed over the entire container length via the gratings and rises upwards through the cargo. The air is then drawn off from the container's upper return air opening via the air channel left clear beneath the container roof and cooled in the refrigeration unit. If the maximum load height is exceeded, there is not enough space left for the air to circulate properly.

Due to the refrigeration unit fitted onto their end face, clip-on containers are longer than integral containers, while the latter have a smaller cargo capacity. Close to the refrigeration unit, there is a ventilation flap which, depending upon its setting, allows a proportion of the circulating air to escape, so drawing fresh external air into the container (see Fig. 89).

Figure 89: The Figure shows the ventilation flap which can be used to control the supply of fresh air when transporting goods of vegetable origin.
Since there are many different models of fresh air flaps and many different procedures for using them, the settings specified in the shipper's cooling order must always be followed to the letter.
Photo: U. Schieder

Such controlled fresh air exchange allows harmful metabolic products from goods of vegetable origin, such as carbon dioxide or ethylene, to be removed and oxygen to be supplied. The flap should not be opened more than necessary as the incoming external air must additionally be cooled, so increasing the load on the refrigeration unit.

Figure 90: Gratings in the floor of a refrigerated container, which ensure uniform distribution of the refrigerated air;
Photo: U. Schieder

Figure 91: A blocked defrost drain caused the water to flow out through the ventilation openings, where it froze. This blocked the floor gratings, so preventing sufficient air circulation.
Photo: Nielsen [24]

To ensure adequate circulation of the cold air, the floor is provided with gratings (see Fig. 90). Fig. 91 shows an incident of loss. In addition, the side walls of the container are "corrugated", which ensures satisfactory air flow there too. Fig. 92 shows several corrugations. When packing the container, suitable free space of approx. 15-20 cm must remain above the cargo in order to permit air flow here as well (see Fig. 92).

Figure 92: The red line in the container indicates the maximum cargo height. The free space above the red line ensures that the return air, which has been "warmed up" by the cargo stack, can flow back to the refrigeration unit. The corrugations in the outer insulation ensure that the cold air flows around the outside of the cargo block of the fully, flush-loaded container.
Photo: U. Schieder

A mark indicates the maximum admissible cargo height. In usual container types, fresh air exchange is currently still adjusted manually; a microprocessor-controlled method has, however, been developed which makes it possible to carry out ventilation in accordance with a predetermined program. Using this method, it is possible, for example, not to begin ventilation until 72 hours have elapsed, in order to remove any heat which has been absorbed during packing. Ventilation may then be provided at specific time intervals in order to minimize any associated increase in temperature.

Use of additional intelligent sensors makes it possible to measure the carbon dioxide and/or oxygen content of the cooling air and adapt ventilation to the specific requirements for the particular product. Since ethylene production is proportional to carbon dioxide production, this ripening gas can also be successfully monitored in this way.
The doors constitute a weak point in both integral units and porthole containers. Wear to rubber door gaskets or improper handling may result in the doors no longer closing correctly, so that they are no longer sealed against rainwater and the like.

Figure 93: This container roof has suffered considerable damage during handling with a spreader.
Photo: Nielsen [24]

During transport of chilled and frozen goods, water ingress may lead to cargo spoilage or to ice formation in the door area (see Figs. 93-95).

Figure 94: Damage to the container roof has resulted in warping of the doors. As a result, rainwater was able to get inside and formed a layer of ice in the door area.
Photo: Nielsen [24]

Figure 95: Rainwater has got inside in the door area in this case too, but the cause was a leaky rubber door gasket.
Photo: Nielsen [24]

In addition, refrigeration capacity has to be increased to compensate for losses due to cold air leakage. The temperature of the cold air which is blown in is recorded, for example, by means of a Partlow recorder or data logger (see TIS).

15.3.1.3 Low-temperature refrigerated containers

Using this type of container it is possible to transport cargoes, such as very highly perishable tuna, at a temperature of -60°C.

The "eutectic point" (E.P.) is at -62°C and, at this temperature, all the water in the cells of the product is completely frozen, preventing microbial biotic activity and therefore preventing any loss of quality to the product (see Section 15.3.4).

15.3.2 Chilling and cold chains

Chilling is taken to mean the removal of heat in order to reduce the temperature of the air to below the ambient temperature or to maintain the refrigeration temperature in the refrigerated container. The refrigeration capacity for maintaining the refrigeration temperature must be sufficient to remove the quantities of heat which get into the refrigerated container through the insulated walls from the environment, the chilled goods, fan operation, addition of fresh air, the respiration heat of goods of vegetable origin. Goods are generally prechilled before being packed in the container.

The refrigeration capacity required to chill the foodstuffs is determined by the specific heat capacity of the goods over the chilling range, by the temperature of goods before and on completion of chilling, by the storage temperature and the chilling time.

The cold chain is the unbroken chain of storage facilities and means of transport from the manufacture through to the consumer in which the prescribed freezing temperature is constantly maintained (see Fig. 96).

The cold chain must keep the foodstuffs at an uninterrupted, uniform temperature so that they reach the consumer without suffering loss of quality. Accordingly, one of the crew's duties is to ensure strict compliance with transport temperatures from when the cargo is accepted until it is unloaded.

The greater the sensitivity of the cargo, e.g. stored blood, the faster must the refrigerated container be reconnected at the terminal or for onward transport.

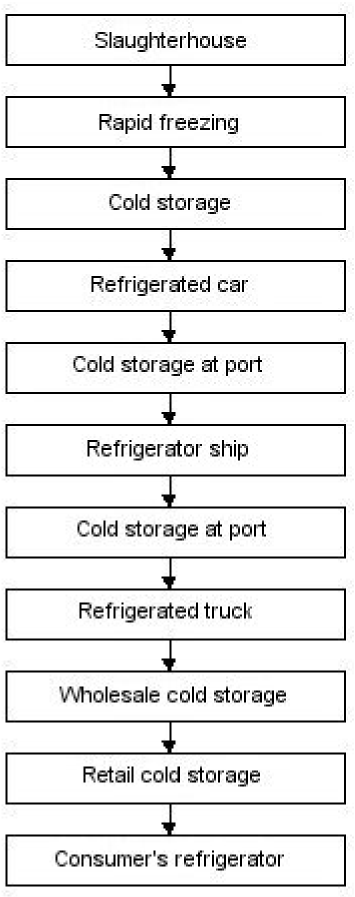


Figure 96:
Diagram of cold chain

15.3.3 Chilled storage of foodstuffs

Chilled storage of highly perishable foodstuffs restricts the activity of microorganisms and retards biochemical reactions.

Reducing temperature doubles or triples the storage life of foodstuffs such that, by providing product-specific temperature and humidity/moisture conditions during transport, chilled goods can be treated as fresh foodstuffs after transport.

15.3.4 Freezing and freezing chain

Food preservation by freezing is a process for extending the storage life of foodstuffs over the long-term by storage at low temperatures; the process comprises both freezing of the foodstuffs and their storage once frozen. The water in foodstuffs is never present in pure form, but instead forms an unsaturated solution of mineral salts, carbohydrates, organic acids and other soluble substances. Depending upon the concentration of the cytosol, the freezing point is -0.5 - -3°C.

The freezing curve can be divided into chilling and ice separation stages. Crystallization of ice once the temperature falls below the freezing point increases the concentration of the solution, so depressing the freezing point of the remaining liquid. The water freezes gradually over a wide temperature range until the eutectic point, at which the water and solutes crystallize out together, is reached at about -62°C.

Figure 97 shows the quantity of crystallized ice in various foodstuffs as a function of freezing temperature. While in strawberries and meat 70% of the water is completely frozen at between -1 and -5°C, only 30% of the water in white breadcrumbs is frozen at such temperatures. At temperatures below -10°C, only a little further water freezes in strawberries and meat. The freezing process is virtually complete for white breadcrumbs only from -20°C and for strawberries and beef only from -30°C.

This freezing curve explains why frozen goods are generally frozen to core temperatures of -18°C to at most -30°C. Some 0.3 - 0.49 g of water/kg of dry solids remain in the tissue as residual liquid. Even at lower temperatures, this residual liquid does not freeze, and is sufficient to permit enzyme activity.

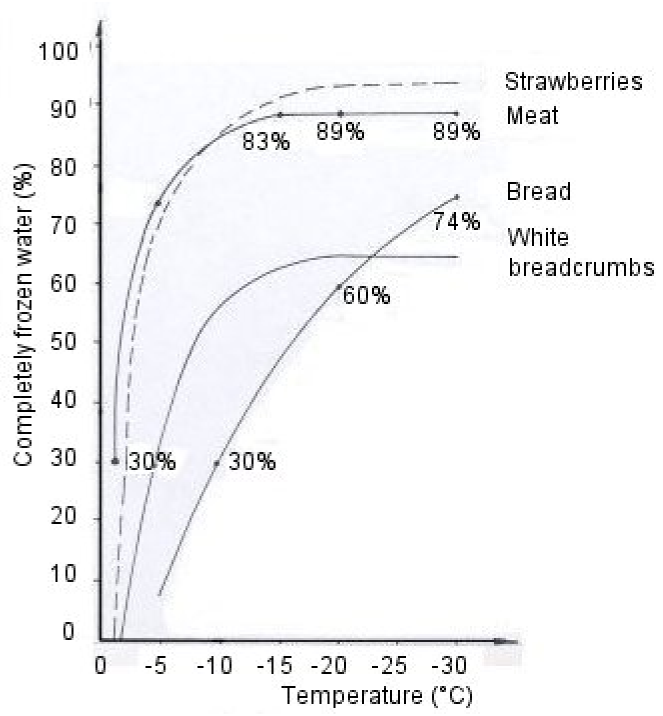


Figure 97: Proportion of completely frozen water in various foodstuffs from the onset of freezing to -30°C [57]

Frozen goods thus do not have an unlimited storage life, but are instead classed as preserved foods. The low-temperature containers described in section 15.3.1.3 are an exception.

At temperatures of -60°C, virtually 100% of the water has frozen and, theoretically, the goods have an unlimited storage life. The conventional industrial rapid freezing process (flash freezing) which uses freezing plant capable of operating at a freezing rate of 1 cm/h or more ensures that the cell structure is largely retained and consequently little drip loss occurs on thawing, i.e. the quality of the frozen goods is maintained.

15.3.5 Frozen storage of foodstuffs

Frozen storage (low temperature refrigerated storage) limits microbiological and biochemical changes to a greater extent than chilled storage. As has been shown, at the storage temperatures of -12 - -30°C, the majority of the water is completely frozen, such that the microorganisms can no longer multiply and biochemical reactions, especially those catalyzed by enzymes, proceed very much more slowly. This results in a longer storage life than for chilled goods.

The changes undergone by frozen goods are time- and temperature-dependent: the lower the temperature, the longer the storage life and the lesser the changes in color, flavor, odor and vitamin content.

The temperature range between freezing point and approx. -12°C is avoided because, due to the still elevated unfrozen water content, the goods may suffer serious degradation in quality due to the possible microbiological and enzymatic changes and changes in freezing and consistency. An uninterrupted freezing chain must be ensured with frozen goods too in order to avoid any disadvantageous changes in the frozen goods such as recrystallization due to the temperature fluctuations caused by transient thawing.

The following is an example of an incident of loss:

Strawberries for making jam were to be shipped from Poland to Germany in plastic barrels.

The strawberries were precooled to a temperature of 0°C in 220 plastic barrels, each holding 95 kg. The truck body was cooled to -20°C.

On arrival in Germany (7 days later) the strawberries exhibited a fruit juice-like fermented odor and a fermented flavor. The juice was foaming as a result of the fermentation processes.

Due to their low mechanical strength, strawberries are classed as soft fruit and, due to their high water content (90%) are particularly susceptible to molds and yeasts. Grey mold rot (Botrytris cinerea, see Fig. 98), wet rot (caused by the Mucorales fungus Rhizopus nigricans, see Fig. 99) and yeasts (Saccharomyces cerevisiae, see Fig. 100) may cause the strawberries to ferment.

The truck's refrigeration unit was only capable of maintaining a certain precooled temperature below freezing, but was not able to cool down a "warm" load. The strawberries ought to have been rapidly frozen to -20°C before transport.

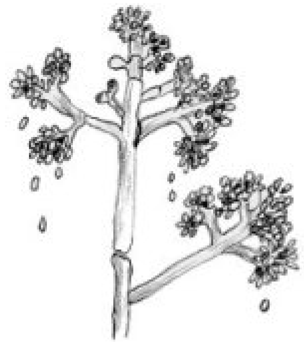


Figure 98:
Grey mold (Botrytis cinerea),
which causes grey mold rot

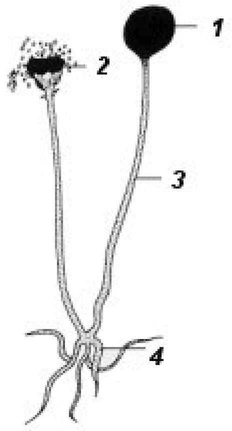


Figure 99:
The mold Rhizopus nigricans,
which causes wet rot

1 - sporangium
2 - burst sporangium
3 - sporangiophore with high plasma content
4 - rhizoids

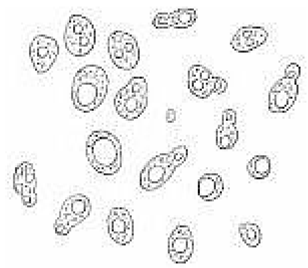


Figure 100:
The yeast Saccharomyces cerevisiae

At a precooling temperature of only 0°C, sufficient cell water was still in the liquid state for molds, yeasts and enzymes to be able to cause the cytosol to ferment.

Moreover, the exclusion of oxygen may have resulted in anaerobic respiration of the strawberries. The same situation can also arise in containers as they are not suitable for freezing goods.

15.4 Packaging of chilled & frozen goods

15.4.1 Demands made of packaging

The packaging used for highly perishable foodstuffs has to provide protection against external influences, such as atmospheric oxygen, water vapor, light, microbial attack, foreign odor, dust and contamination.

The packaging materials must not react with the goods (foodstuffs). The packaging must be readily stackable, resistant to compression, impact and breakage as well as providing protection against moisture, i.e. the cartons must be made from wet strength paperboard since moisture will otherwise make them bulge, especially in the lower layers (see Fig. 101).

Figure 101:

When the cardboard was selected for these orange cartons, insufficient attention was paid to whether the material was adequately insensitive to moisture or exhibited wet strength.

Moisture in the cardboard has caused the cartons in the lower layers on the pallet to bulge out considerably and they now run the risk of being damaged when moved about with forklift trucks.

Such inadequate packaging can result in considerable damage, if the pallet width was originally precisely matched to the truck width.

Photo: Förster/ Ahrens [12]

Packaging also plays an ever greater promotional role, since chilled products are provided with attractive sales packaging, in which they are also transported. See-through packaging allows the purchaser to assess the contents to a certain degree. For example, the purchaser will be disturbed by drops of condensation water visible on the inside of the packaging. The current trend is towards transporting goods in the retail portions (foodtrays (small packages)) in which they will be offered for sale to the customer on the retailer's shelves.

Packaging must additionally be environmentally friendly and recyclable: packaging used for highly perishable goods cannot generally be reused for reasons of hygiene.

15.4.2 Packaging containers

Common packaging containers for fresh fruit and vegetables include cartons, frequently of corrugated board, fruit crates (wooden and cardboard trays) with cushioning, jointed cases, chip baskets and bags made of woven cloth, e.g. jute bags for potatoes.

The following requirements are placed on packaging containers for fresh fruit and vegetables, in accordance with metabolic processes and transport stresses:

- optimum permeation of the packaging units with cooling air for chilling the product
- water vapor permeability of packaging in accordance with the product's requirements, in order to prevent mold and rot due to excessive moisture, while also preventing wilting, shrinkage and weight loss due to drying-out
- optimum gas permeability (optionally by perforation), which must firstly supply oxygen in fresh air and secondly remove harmful substances such as carbon dioxide and ethylene
- strength, in order to avoid bruising. To fulfill these requirements, cartons for fresh fruit and vegetables have perforations which ensure that air flows through the packages or circulates around the product.

Fig. 102 illustrates vertical air flow through perforated cartons, a vital point being that the perforations in the stacked cartons must correspond exactly so that the air can flow vertically through all the cartons. This is why the perforations are arranged directly opposite each other.

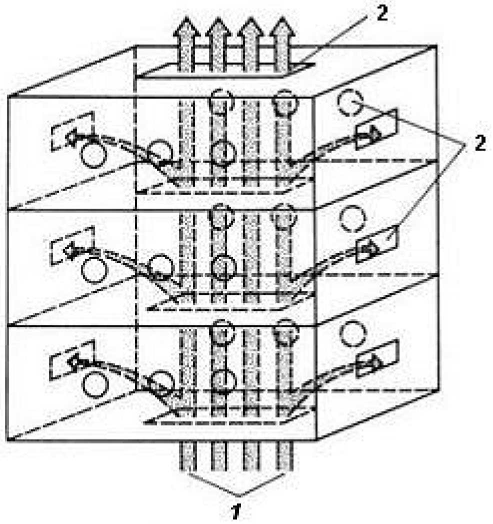


Figure 102:
Vertical air flow through perforated cartons

1 - vertically flowing cooling air
2 - perforations in cartons

Table 9 shows the perforation content for the transport of a number of tropical and subtropical fruits.

Cargo type	Exporting country	Packaging container	Packaging material	Tare in g	Total tare in g	Perforation content in %
Grapefruit	Cuba	Folding telescope carton	D WP 1 B WP 2	D 350 B 550	900	1.68
Tangerines/ mandarins	Cuba	Folding telescope carton	D WP 1 B WP 1	D 340 B 400	740	1.65
Mandarins	Uruguay	Folding telescope carton	D WP 1 B WP 1	D 400 B 640	1,040	2.15
Oranges	Uruguay	Folding telescope carton	D WP 1 B WP 2	D 500 B 780	1,280	2.13
Bananas	Ecuador	Folding telescope carton	D WP 1 B WP 2	D 450 B 600	1,050	8.18

Table 9: Perforation content of shipping cartons for the transport of tropical and subtropical fruits

L - Lid part   CB 1 - Corrugated board, single wall

B - Base part   CB 2 - Corrugated board, double wall

The cartons for bananas from Ecuador are optimally perforated for vertical air flow. The lid and base parts of folding telescope cartons for bananas are each respectively provided with an opening of 280 cm² or 220 cm², so allowing unhindered vertical air flow. The end faces are provided with 5x8 cm holes, which also serve as handles (see Fig. 103).

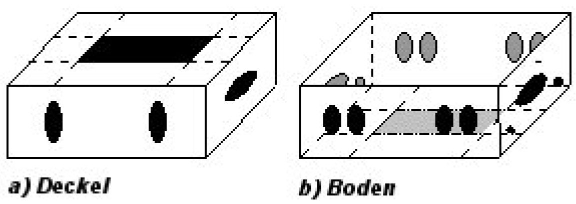


Figure 103: Folding telescope cartons for bananas, Cavendish variety, from Ecuador

The proportion of the total surface area of a closed folding telescope carton occupied by perforations amounts to 8.18%. In addition, the bananas, which are additionally packaged in perforated polyethylene bags in the cartons, may be easily checked for ripeness and any condensation water formation.

Fig. 104 shows an example of packaging for Cape grapes. Fruit is often also wrapped in an inner packaging of paper, e.g. pears from Brazil in sulfate paper (as protection from light). Chicory is protected from light and drying out with dark blue paraffin paper. Oranges are wrapped up in tissue paper, which is often treated with fungicidal/bactericidal

substances. The fruit is cushioned against pressure and impact and is often packed in shaped trays (e.g. of rigid PVC film), which separate the layers of fruit.

Kiwifruit are packed in a single layer in attractive wooden, plastic or cardboard trays fitted with plastic inserts, to ensure impact resistance. Peaches are also transported in flat fruit crates with plastic inserts. Heads of broccoli and lettuce are individually protected with film and packaged in fruit crates.

Frozen fruit and vegetables are transported in shipping packages in the form of folding cartons of corrugated board, which are usually treated with paraffin to prevent evaporation losses.

Figure 104:
Cape grapes in corrugated board carton

To ensure a vertical flow of cooling air, lid and base have each been provided with a large opening; in addition four round holes have been provided, along with four holes in the edge area.

The grapes are protected by a perforated polyethylene bag. Butter and fats are packaged in millboard cartons provided with an internal lining designed to make the cartons largely impermeable to air and oxygen, so as to be able to prevent oxidative reactions, which lead to rancidity. Meat and fish are shipped in cartons of millboard or corrugated board and in wooden cases.

15.4.3 Packaging materials

15.4.3.1 Wooden shipping packages

Lumber is a hygroscopic packaging material. Air dry lumber is considered container dry if its equilibrium moisture content is 70 - 75%, i.e. its water content is 12 - 15%.

It very often happens that cases are made from lumber which is too green and thus too wet (water content > 15%), resulting in the growth of mold on fruit and vegetables, for example.

15.4.3.2 Paper, cardboard and paperboard shipping packages

These materials are also hygroscopic packaging materials. Increasingly, corrugated board is preferred to millboard because it weighs less while being similar in strength. However, the moisture sensitivity of paperboard must be taken into consideration, since carton strength may be noticeably reduced in damp conditions and the cargo being transported may start to grow mold, just as with excessively wet lumber.

In practice, all hard boards lose strength when damp, so meaning that the stack height for fruit cartons has to be limited, at normal water content, to nine layers for a six week voyage, to prevent the stack from collapsing.

If wet strength cartons are not used, there is a risk, over a longer voyage, of the cartons collapsing and the fruit becoming damaged due to pressure. This also leads to a reduction in the air openings and thus in the volume of circulating air (see Fig. 102).

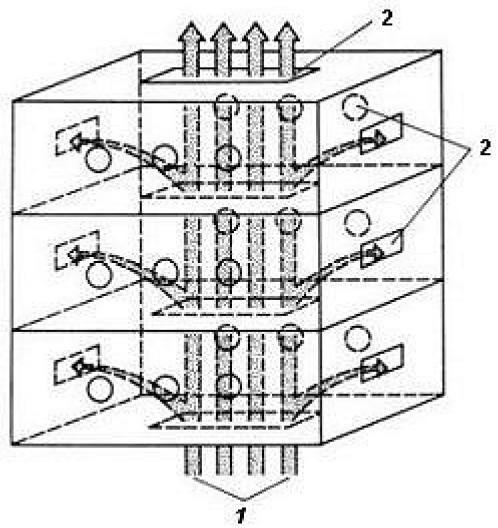


Figure 102:
Vertical air flow through perforated cartons

1 - vertically flowing cooling air
2 - perforations in cartons

To improve the wet strength of cartons, the paperboards are generally rendered water repellent (by waxing, coating or impregnation).

In folding telescope cartons, the lid parts generally consist of single wall corrugated board (CB 1, see Table 6) and the base parts of double wall corrugated board (CB 2, see Fig. 105), for greater strength.

Cargo type	Exporting country	Packaging container	Packaging material	Tare in g	Total tare in g	Perforation content in %
Grapefruit	Cuba	Folding telescope carton	D WP 1 B WP 2	D 350 B 550	900	1.68
Tangerines/ Mandarins	Cuba	Folding telescope carton	D WP 1 B WP 1	D 340 B 400	740	1.65
Mandarins	Uruguay	Folding telescope carton	D WP 1 B WP 1	D 400 B 640	1,040	2.15
Oranges	Uruguay	Folding telescope carton	D WP 1 B WP 2	D 500 B 780	1,280	2.13
Bananas	Ecuador	Folding telescope carton	D WP 1 B WP 2	D 450 B 600	1,050	8.18

Table 6: Perforation content of shipping cartons for the transport of tropical and subtropical fruits

L - Lid part	CB 1 - Corrugated board, single wall
B - Base part	CB 2 - Corrugated board, double wall

At an equilibrium moisture content of 65 - 70%, the water content for corrugated board is 5 - 8%. Complaints should be lodged if cartons are obviously of inadequate strength.

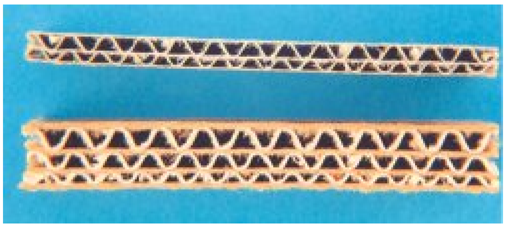


Figure 105:
Single wall corrugated board (top),
Double wall corrugated board (bottom)

15.4.3.3 Use of plastic films

When plastic films are used for frozen goods, this packaging material must display adequate strength and elasticity. Both the films and their closures must be able to withstand the stresses which arise during filling, freezing, storage, transport and thawing. Elasticity must be sufficient even at low temperatures. The requirements placed in plastic films as a packaging material center on two aspects:

1. Elasticity, to ensure good handling properties and to prevent damage to the surfaces of the packaged goods. Stiffening of the films when exposed to cold is a typical characteristic of thermoplastics.
   Plasticizers are used to increase elasticity, especially low temperature flexibility, and to prevent brittle fracture caused by mechanical stress at film freezing temperatures.

2. Water vapor and gas permeability of plastic films. It is particularly important with frozen goods for the films to be extensively water vapor tight, to prevent loss of quality and weight. Films 0.1 mm thick should display water vapor permeability which does not exceed 0.5 g/m² over 24 hours where used for fish, meat and poultry and 1 g/m² over 24 hours where used for fruit and vegetables. The above values also apply to the seal seams.

For fresh fruit and vegetables, on the other hand, the plastic films must display moderate water vapor and gas permeability in order for their metabolic processes to continue in chilled storage. This is generally achieved with perforations. Table 10 illustrates the water vapor permeability of certain packaging films.

Water vapor permeability at 20°C in g/m² over 24 hours
Film thickness: 0.1 mm
Humidity gradient: 85%

PVC - rigid films	6 - 8
PVC - flexible films	8 - 12
High pressure polyethylene films	0.6 - 0.8
Low pressure polyethylene films	0.1 - 0.2

Table 10: Water vapor permeability
of certain packaging films [6]

In the case of goods which are additionally provided with outer packaging (cartons etc.), high pressure polyethylene films or low pressure polyethylene films are wholly adequate. Where stress is extreme, three-ply films must be used.

Three-layer films are used in the absence of outer packaging.

For even tougher use or greater stress, a polyamide coating is advisable. It is possible, however, to manage without film, e.g. in the case of fish fingers, if the board stock used for the cartons is polyethylene-coated.

Packaging has an effect on surface diffusion. The lower the water vapor permeability of the packaging material, the lower the evaporation level and consequently the lower the weight loss. If the packaging is absolutely impermeable to water vapor, the microclimate inside the package becomes increasingly saturated with water vapor, which is associated with an increase in microbiological spoilage.

15.5 Stowage of chilled & frozen goods in refrigerated containers

15.5.1 Stowage of chilled goods

In container stowage, a distinction is generally made between chilled goods and frozen goods. Chilled goods, consisting predominantly of vegetable products (fruit, vegetables), come under the influence of two heat sources:

The entry of external heat into the container through its walls, floor and roof, and the heat which is produced by the cargo itself and has to be removed. In this case, air must circulate not only around the cargo but also throughout the cargo (see Figs. 102 and 103).

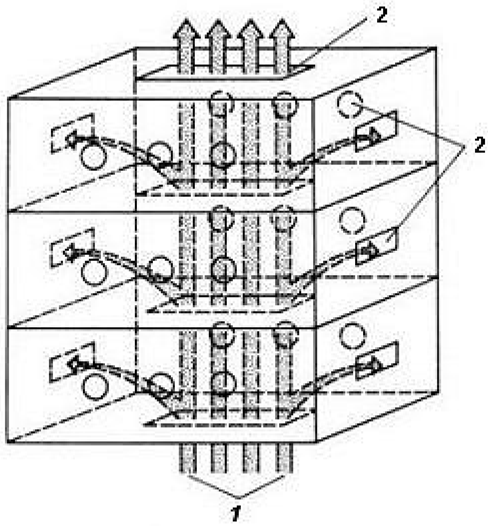


Figure 102:
Vertical air flow through perforated cartons

1 - vertically flowing cooling air
2 - perforations in cartons

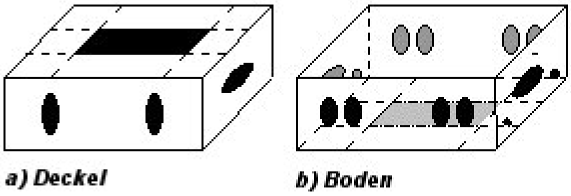


Figure 103: Folding telescope cartons for bananas, Cavendish variety, from Ecuador

In the case of chilled goods, respiration heat and packaging type are of considerable significance. The perforation openings in the packaging differ in size and/or number depending on the respiration heat (see Section 15.4).

When packing a container with chilled goods (fruit, vegetables), it is important for the cooling air to be able to flow unhindered through the perforation openings and gaps between the cartons, i.e. the cartons must be stowed precisely "in line" (see Fig. 106).

Figure 106:
Ventilated stowage:
This is the best possible type of stowage for chilling plus goods or chilled beef. This well-ventilated stowage method ensures that cooling air circulates around each carton and a uniform chilling temperature may thus be achieved.
Photo: Förster/Ahrens [12]

If deep-frozen meat is at its optimum temperature when loaded, it is not necessary to leave these gaps during stowage. All that is necessary with frozen goods is for the subzero temperatures to be maintained around the stowed cargo in the floor, side and ceiling areas.

This is ensured by the corrugations in the side walls, the space in the ceiling area and the gratings in the floor area.

15.5.2 Stowage of frozen goods

Frozen goods, consisting primarily of animal products (meat, fish) which are already at their optimum temperature on packing, have merely to be protected from the effects of external heat. They are stowed tightly together in a block without spaces.

It must be ensured that subzero temperatures are maintained in the floor, side and ceiling areas, that the cooling air flows right round the block, i.e. that the cartons do not come into contact with the heat entering the container through its walls, floor and ceiling.

It must thus be ensured that the cartons cannot interrupt the air flow through the corrugations in the side walls. A free space of at least 8 - 10 cm must be left between the top of the cargo block and the container roof. The maximum cargo height is marked in the containers (Max. Load Height/Maximale Ladungshöhe, see Fig. 92).

Figure 92: The red line in the container indicates the maximum cargo height. The free space above the red line ensures that the return air, which has been "warmed up" by the cargo stack, can flow back to the refrigeration unit. The corrugations in the outer insulation ensure that the cold air flows around the outside of the cargo block of the fully, flush-loaded container.
Photo: Schieder [49]

15.6 Checklist

A checklist for correct packing of a refrigerated container should include at least the following points:

- Tightness inspection of the container to be packed: has the container been damaged during previous transport (damage, cracks, holes)? Visual inspection from inside when the container is closed.
- Cleaning of the container of cargo, cargo securing and packaging residues. Deodorization of the container in the case of odor tainting, e.g. by citrus fruits.
- Is the cargo homogeneous (same carton size and same/different contents)? If the cargo is mixed, consideration must be given to whether the types of goods are compatible (see Section 13), e.g. respiration rate, ethylene and carbon dioxide production and/or sensitivity, degree of ripeness etc.
- How long is the planned transport time? Is the storage life of the goods involved adequate?
- Is the refrigeration unit functioning correctly? Calibration of thermostat temperature.
- Refrigerated containers should be subjected to regular pre-trip inspections (PTI).
- When bringing refrigerated and heatable tank containers into service, it must be ensured that the temperature is set correctly and that, in the case of refrigerated containers, the temperature recorder is running and the temperature is displayed.
- With tank containers, it must be checked whether the pressure and vacuum relief valve is clean and/or functional.
- Condition of the rubber door gasket.

- Drain plug present and inserted?
- Prior to packing, the containers have to be precooled to the temperature required for the cargo (compliance with cold chain).
- To comply with the cold chain, packing or unpacking must be performed quickly. In breaks in packing or unpacking, the doors of the container must be closed.
- How high is the transport temperature? What is the critical temperature? What air exchange rate is required? The air exchange rate in containers can only be influenced to a limited degree.
- Have the packaging or its contents been visibly damaged?
- Are all seals (air-tight closure, gasket, lead seal, closure wiring), especially the door seals and closures, in good order?
- Are the documents required for transport and hand-over complete?
- In the case of containers bound for Australia and New Zealand, are all the necessary certificates to hand?

16 Container transport of specific chilled & frozen goods

16.1 Fruit

Characteristics and fitness for container transport
Fruit comprises the edible fruits and/or seeds of perennial woody or semiwoody plants (trees, shrubs) and herbaceous perennials.

The following classification based on the botanical features of the fruits has proved effective for transportation purposes and thus for container transport:

- Berry fruit (fresh currants, gooseberries, raspberries, blackberries, strawberries, blueberries, grapes)
- Stone fruit (cherries, plums, apricots, peaches, nectarines)
- Pomaceous fruit (apples, pears, quinces)
- Wild fruit (elderberries, cranberries)

Tropical and subtropical fruit includes types such as bananas, pineapples, citrus fruit, kiwifruit, mangoes, avocados, together with exotic fruit such as cherimoya, granadillas, guava, Japanese persimmons, starfruit, kumquats, lychees, papaya, passion fruit, ground cherries and others (see Fig. 107).

Figure 107: Tropical and subtropical fruit;
Photo: Ragna Scharnow

Fruit exhibits high, 2nd order biotic activity (BA 2), i.e. respiration processes predominate due to separation from the parent plant and the consequent absence of any further supply of new nutrients.

The high water contents typical of fruit, which range from 80% (plums) to 85% (strawberries), mean that fruit is placed in water content class 3 (WCC 3) and is therefore highly perishable.

The sugar/acid content of fruit is the dominant feature. Examples of constituents are:

- Carbohydrates (mainly in the form of sugar): 8% (fresh currants) to 18% (grapes)
- Fruit acids: 0.3% (pears) to 7% (lemons)
- Vitamin C content: 10 mg/100 g (bananas) to 150 mg/100 g (blackcurrants)
- Minerals: 0.5%

Most types of fruit are harvested at the preclimacteric stage (picking or industrial ripeness) because they are capable of post-ripening; they are also climacteric to a greater or lesser extent, i.e. they produce carbon dioxide and

ethylene in the course of ripening.

Transport temperatures for fruit are often far above freezing point, as they may be at risk of chilling damage (see Table 11).

Type of cargo	Lowest supply air temperature in °C	Transport temperature	Admissible variations in K	Humidity in %
Pineapple, ripe-green		10.0 - 12.0	0.5	85 - 90
Pineapple, ripe		5.0 - 7.0		
Oranges		4.5	0.5	85 - 90
Apples	-2.0	-0.5 - 1.5	0.5	85 - 90
Apricots	-1.5	-0.5	0.5	80 - 85
Avocados		1.0 - 9.0	0.5	80 - 85
Bananas	11.5	11.5 - 12.2	0.1	85
Pears	-2.0	-0.5	0.5	85 - 90
Blackberries		-0.5	0.5	80 - 85
Strawberries	-0.5	0.0	0.5	85 - 90
Grapefruit		11.0	1.5	85 - 90
Blueberries	-2.0	-0.5	0.5	85 - 90
Raspberries	-1.0	-0.5	0.5	80 - 85
Cherries	-1.0	-0.5	0.5	85 - 90
Limes		11.0	0.5	85 - 90
Mangoes		11.0	0.5	85
Melons		12.0	1.0	75 - 85
Mirabelle plums	-1.5	0.0	1.0	80 - 85
Peaches	-1.5	0.0	0.5	85 - 90
Plums	-1.0	-0.5 - 7.0	0.5	85 - 90
Cranberries	1.0	3.0	0.1	90
Quinces	-1.5	0.0	1.0	80 - 85
Greengages		0.0	0.5	85 - 90
Gooseberries		0.0 - 1.0		85 - 90
Dried fruit		-3.0 - 2.0		75 - 85
Grapes	-1.5	-0.5	0.5	80 - 85
Lemons		10.0 - 12.0		80 - 85

Table 11: Temperature and moisture/humidity conditions for fresh fruit storage during transport; Becker [5]

Fruit requires temperature, humidity/moisture and ventilation conditions (SC VII) because respiration processes must be specifically controlled and dormancy temperatures must be established. Ventilation ensures, on the one hand, that the necessary oxygen is supplied and, on the other, that harmful gases (carbon dioxide, ethylene) are removed. Refrigerated containers with a fresh air supply and CA containers are the most suitable for the temperature-controlled transport of fruit.

Transport instructions and damage
Before packing, the containers must be thoroughly cleaned, ventilated and, if required, disinfected.

Packaging
The cargo is prepared for shipment in packing stations:

- Inspection of fruit for blemishes and freshness

- Cleaning and, in some cases, application of fungicides (e.g. for bananas and citrus fruit)

- Selection of the most appropriate packaging, e.g. wet strength cartons, which are provided with perforations; fruit crates and cases made from resin-free wood; particularly sensitive fruit, such as kiwifruit or grapes, are packaged in a single layer in trays and palletized

Temperature
A written cooling order must be obtained from the shipper. The temperature specified in the order is a compromise between a temperature which prevents premature ripening ("dormancy temperature") and a temperature which is still high enough to prevent chilling damage.

It is clear from Table 11 that, especially for tropical and subtropical fruit, transport temperatures are far above freezing point as chilling damage is to be anticipated even at temperatures above freezing.

Fruit is also particularly sensitive to temperature variations.

Table 12 shows transport temperatures for the frozen storage of fruit of between -18 and -20°C, i.e. at which 80 to 90% of the cytosol is frozen, such that microorganisms and enzymes are made virtually inactive.

Fruit type	Temperature
Pineapple	-18°C
Apricots	-20°C
Pears	-18°C
Blackberries	-18°C
Strawberries	-18°C
Raspberries	-18°C
Fresh currants	-18°C
Cherries	-18°C
Melons	-18°C
Mirabelle plums	-20°C
Cranberries	-18°C
Greengages	-20°C
Rhubarb	-18°C
Gooseberries	-18°C

Table 12: Transport temperatures
for the frozen storage of fruit;
Becker [5]

If the temperature falls below the refrigeration or dormancy temperature, chilling damage may occur, as for example in bananas whose skin turns pinkish-brown. Stripes appear in or under the skin. The flesh of the fruit remains hard and dry and has a mouth-puckering (astringent) flavor. The fruit also loses its ability to ripen. With pineapples, the skin loses its gloss, the flavor is insipid and the crown leaves become detached. In citrus fruit, spots form in the peel (peel discoloration) and the flavor becomes bitter. The commonest kind of chilling damage in fruit, especially in pomaceous fruit, is internal breakdown. In pineapple, chilling increases its susceptibility to black rot.

Interruption of the cold chain and exceeding the specified temperature may result, depending on the length of interruption, in premature ripening of the fruit. Once fruit ripening has begun, many kinds of fruit start to release the ripening gas ethylene. This gas causes other fruit to begin ripening (allelopathy) and, depending on its concentration, considerably accelerates ripening. In some kinds of fruit, e.g. the banana, ripening is a process which, once started, cannot be stopped. Exceeding the maximum upper temperature limit specified for a particular variety of bananas results in "cooked bananas". For this reason, strict compliance with the cold chain must be ensured.

Humidity/Moisture
Table 11 shows that relative humidity must generally be very high, around 80 - 90%, if flabbiness/shriveling and weight loss are to be avoided. Citrus fruit is often waxed to provide protection from drying-out. Pineapples and other kinds of fruit are at particular risk of drying-out and may suffer weight loss of up to 1% and, in extreme cases, even more.

Allelopathy
Pomaceous and stone fruit, being climacteric fruit, produce large quantities of ethylene. Early and late varieties of apple, for example, must accordingly not be stowed together in a container as the metabolic activity of the early varieties will reduce the storage life of the late varieties. The carbon dioxide content of the container atmosphere

should be maintained at 0.5 - 1.0 vol.% by supplying fresh air, so also keeping the content of other ripening gases such as ethylene within reasonable limits. Inadequate ventilation may, as a result of a build-up of carbon dioxide and an insufficient supply of atmospheric oxygen, cause the fruit to change over to anaerobic respiration, which rapidly results in fermentation and rot.
As has already been mentioned, most kinds of fruit are harvested and transported at picking ripeness (preclimacteric). It should, however, be noted that stone fruit (cherries, plums, apricots, peaches, mangoes, avocados) ought to be harvested as shortly as possible before eating ripeness (climacteric) as they do not post-ripen well and otherwise have a turnipy flavor and cannot easily be separated from their stone. However, harvesting at this stage means that only little time is available for transport. This shortcoming may, however, usually be overcome by using CA containers. One exception is grapes (dessert grapes), which are harvested at the climacteric, as they do not post-ripen.

Mechanical influences
The root cause of many types of damage, such as mold and rot, is mechanical damage, such as squashing, cracking, bruising. Pineapples, for example, are extremely pressure-sensitive and can develop "pressure sores" and are accordingly specially packaged in "Japanese garden" type (compartment) packaging. Squashed citrus fruit forms "goose pimples". Mangoes are highly perishable as even the smallest of cracks results in spoilage. All stem-ends must be removed from kiwifruit as they could injure adjoining fruits.

Odor
Due to their high content of highly volatile essential oils in the peel, citrus fruits in particular are a highly odor-contaminating cargo and must thus not be stowed in a container together with other kinds of fruit and vegetables. Care must also be taken to deodorize the containers before subsequent packing with other foodstuffs.

Insect infestation/Diseases
The Mediterranean fruit fly (Ceratitis capitata), for example, is a quarantine pest which in particular attacks thin-peeled citrus varieties. Mangoes infested by the mango fruit fly must be destroyed. Peaches infested by the San José scale cannot be exported (quarantine pest). Attack by the cherry fruit fly is manifested externally by a brown, sunken area near the stem-end.

Damage by molds and bacteria
Cut stems on bananas and pineapples are treated with a fungicidal paste to prevent mold. Citrus fruits are susceptible to green and blue mold and, after washing, optional finishing (dye bath) and waxing, are accordingly treated with fungicides, such as diphenyl, orthophenylphenol (OPP) and thiabendazole (TBZ). Since fungicides impair the flavor of the peel, indication of their use is mandatory. Grapes are highly susceptible to grey mold rot. Pomaceous fruit is affected by various rots, e.g. blue mold rot (apples, pears), brown rot (apples), grey mold rot (pears).

16.2 Vegetables

Characteristics and fitness for container transport
Vegetables are edible plant parts, such as leaves, shoots, stalks, flowers, fruits, seeds, buds, roots, rhizomes (rootstocks), which are predominantly obtained from annual and herbaceous plants.

Vegetables, like fruit, can be classified in accordance with various criteria, but the following classification based on the part of the plant which is used is effective for transportation purposes and thus for container transport:

- Leaf vegetables: corn salad, garden lettuce, spinach, chard, endive, radicchio
- Stalk vegetables: asparagus, chicory, chives
- Brassicaceous vegetables: white cabbage, red cabbage, savoy cabbage, Brussels sprout, curly kale, Chinese cabbage
- Bulb vegetables: onions, leeks, shallots, garlic, sweet fennel
- Root vegetable: horseradish, black salsify, carrots, garden radish, celeriac, radishes, beetroot, turnip varieties, yams, cassava, tavo root, Jerusalem artichoke, jicama
- Flower vegetables: artichoke, cauliflower, broccoli
- Pod vegetables: peas, beans
- Fruit vegetables: cucumbers, tomatoes, sweet pepper, pumpkins, melons, courgettes, zucchini, aubergines, egg-plants, horned melon, gem squash, golden squash
- Sprout vegetables: soybean sprouts, mung bean sprouts, alfalfa seed sprouts, chickpea sprouts

Strictly speaking, potatoes are neither fruits nor vegetables, but they are nevertheless items of commerce in the fruit and vegetable trade.

A comparison of the classification criteria for fruit and vegetables (see Table 13) shows that vegetables, like fruit, exhibit elevated, 2nd order biotic activity (BA 2) and a high water content (WCC 3); the water content of curly kale is 80% and that of cucumbers as much as 97%.

	Fruit	**Vegetables**
1	Fruit comprises the edible fruits and/or seeds of perennial woody or semiwoody plants (trees, shrubs) and herbaceous perennials. Types of fruit: pomaceous, stone, berry, shell fruit.	Vegetables are leaves, stalks, roots, flowers, fruits or seeds predominantly obtained from annual and herbaceous plants. Types of vegetable: leaf, stalk, root, bulb, brassicaceous, fruit and pod vegetables.
2	Fruit exhibits high, 2nd order biotic activity (BA 2).	Vegetables exhibit high, 2nd order biotic activity (BA 2).
3	Having a water content of 80% (plums) to 85% (strawberries), fruit belongs to water content class 3 (WCC 3)	Having a water content of 80% (curly kale) to 97% (cucumbers), vegetables belong to water content class 3 (WCC 3)
4	Constituents: carbohydrates (mainly sugar): 8% (fresh currants) - 18% (grapes); fruit acids: 0.3% (pears) - 7% (lemons); vitamin C content: 10 mg/100 g (bananas) - 150 mg/100 g (blackcurrants); minerals: 0.5% = sugar/acid content dominates.	Constituents: carbohydrates (mainly starch): 2% (cabbage lettuce) - 15% (black salsify); fat: 0.6% (asparagus) - 1% (sweet pepper); protein: 1% (tomatoes) - 6% (peas) = starch content predominates
5	Most types of fruit are to a greater or lesser extent climacteric and are harvested at the preclimacteric stage (picking ripeness) as they are capable of post-ripening.	Vegetables are not climacteric and, with the exception of tomatoes, are harvested at the climacteric stage (eating ripeness) as they are not capable of post-ripening.
6	Risk of chilling damage far above freezing point.	Transport temperatures are very close to freezing point.

Table 13: Comparison of fruit and vegetables

Fruit and vegetables differ with regard to their constituents, with the sugar/acid content dominating in fruit and the starch content dominating in vegetables.
Examples of constituents are:

- Carbohydrates (mainly in the form of starch): 2% (cabbage lettuce) - 15% (black salsify)
- Fat: 0.6% (asparagus) - 1% (sweet pepper)
- Protein: 1% (tomatoes) - 6% (peas)

Fruit and vegetables also differ with regard to their climacteric behavior: fruit is usually climacteric, while vegetables are nonclimacteric, which means that fruit can be harvested at the preclimacteric stage, while vegetables cannot be harvested until the climacteric stage because, with the exception of tomatoes, they are incapable of post-ripening.

While chilling damage in fruit occurs far above freezing point, the transport temperatures for vegetables may be very close to freezing point.

Vegetables require specific temperature, humidity/moisture and ventilation conditions (SC VII) because respiration processes must be specifically controlled (dormancy temperatures), so requiring vigorous ventilation to supply oxygen and remove harmful gases, especially carbon dioxide.

Refrigerated containers with a fresh air supply and CA containers are the most suitable temperature-controlled transport.

Transport instructions and damage

Packaging
Perforated plastic bags as the inner packaging in wet strength cartons are conventional for many kinds of vegetables. This type of packaging has proved particularly effective, for example, for sweet peppers, as shriveling and shrinkage of the thin skin rapidly impair quality. Sweet peppers are also transported in palletized cases, fruit crates, nets in food containers.

Carrots are usually washed and packaged in perforated plastic film bags and transported in fruit crates. Water vapor-impermeable film without perforations would cause the carrots to respire anaerobically, rapidly resulting in spoilage (soft surfaces, insipid flavor and hard black spots). Tomatoes are packaged in fruit trays made of wood, cardboard or plastic. It must be possible to provide potatoes and onions with proper ventilation and these products are thus often packaged in wide-meshed bags.

Temperature
It is clear from Table 14 that transport temperatures for most kinds of vegetables are close to 0°C and even as low as -1°C. Berry-like types of vegetables, such as aubergines, egg-plants, cucumbers and tomatoes are an exception and have a transport temperature of 8 - 12°C. Vegetables are also somewhat more tolerant of temperature variations than is fruit (e.g. 0.5 - 2°C).

Type of cargo	Transport temperature in °C	Admissible variation in K	Humidity in %
Artichokes	0.0	0.5	90 - 95
Aubergines, egg-plants	9.0	1.0	85 - 90
Cauliflower	-0.5	0.5	85 - 90
Green beans	3.0	0.5	85 - 90
Broccoli	1.0	1.0	90 - 95
Green peas	-0.5	0.5	85 - 90
Cucumbers	8.0	2.0	85 - 90
Late potatoes	5.0	1.0	85 - 90
Cabbage	1.0	1.0	90 - 95
Kohlrabi	1.0	1.0	90 - 95
Carrots	1.0	1.0	85 - 90
Sweet pepper, green	-0.5	0.5	85 - 90
Radishes	0.5 - 1.0		80 - 85
Rhubarb	1.0	1.0	85 - 90
Brussels sprouts	-3.0 - -1.0		90 - 95
Red cabbage	-1.0 - 0.0		80 - 90
Celery	-1.0 - 0.0		90 - 95
Celeriac	-1.0 - 0.0		85 - 90
Asparagus	1.0	0.5	85 - 90
Spinach	-0.5	0.5	90 - 95
"Teltower" turnip	0.0 - 2.0		85 - 90
Tomatoes, red but hard	-1.0 - 7.0		90
Tomatoes, green	10.0 - 12.0		85 - 90
Savoy cabbage	-1.0 - 0.0		80 - 90
Onions	-1.0 - 1.0		80 - 85

Table 14: Temperature and humidity/moisture conditions for fresh vegetable storage during transport;
Becker [5]

Chilling damage takes various forms, for example being manifested as dark, watery areas on the skin of sweet peppers. The skin becomes detached from the flesh and the inside of the sweet pepper may break down. In tomatoes, chilling damage results in softening of the fruit, associated with brown discoloration of the skin and loss of the ability to ripen. At < 3°C, potatoes become sweet, glassy and take on a watery, grey color. Carrots crack at the surface and the root becomes paler in color. At < 0°C, asparagus very rapidly freezes and dies. Onions and potatoes begin to sprout at > 4°C.

Transport temperatures for the frozen storage of vegetables are -18 - -20°C, as for fruit.

Humidity/Moisture
Table 14 shows that relative humidity is on average still higher (85 - 95%) than for fruit, in order to avoid flabbiness/shriveling and weight loss. Inner packaging in perforated film bags ensures retention of freshness.

When packing a container, fresh vegetables must be provided with particular protection from the action of wet weather (rain, snow) as softening and rot of e.g. potatoes, onions or carrots may otherwise occur. Consignments of new harvest onions are more susceptible to injury than warehoused onions due to their higher water content. Humidity/moisture results in self-heating, sprouting, root growth and decay of the bags, if they are made of jute. Wetting damage makes asparagus rubbery and mushy, which may often be observed if the ends of the asparagus bundles are packaged in paper sleeves to keep the cut surfaces fresh.

Allelopathy
With the exception of tomatoes, vegetables are nonclimacteric. Tomatoes must not be packed in a container together with ethylene-sensitive kinds of fruit and vegetables, nor with cucumbers, which would age more rapidly. Potatoes are extremely sensitive to ethylene, especially to pomaceous fruit, such as apples. The latter cause premature sprouting of potatoes. Carrots are made bitter by the action of ethylene. Leaf vegetables, such as cabbage lettuce, are turned yellow by ethylene, the leaves develop brown spots and are finally lost.

Insect infestation/Diseases
A phytosanitary certificate must, on principle, be provided for container shipment. Potatoes, for example, are affected by quarantinable diseases, such as potato wart, bacterial ring rot, potato moth and powdery scab. The foliage (peduncle) of onions must have been twisted off (not cut off) as there is otherwise a risk of onion neck rot caused by the mold Botrytis allii. The commonest storage disease of tomatoes and washed carrots is grey mold rot, which is caused by the mold Botrytis cinerea. Carrots which have suffered mechanical damage are at particular risk from Fusarium spp. molds.

16.3 Living plants

Characteristics and fitness for container transport
Living plants which are transported comprise trees (including Christmas trees), shrubs, rose bushes, tree scions, seedlings, flower bulbs, herbaceous perennials and pot plants. Living plants can be transported loose with or without a root ball. They are often grouped together in bunches, bags and cases. Depending on their size, they are packaged in root ball cloths of jute or perforated plastic film.

Living plants exhibit high, 1st order biotic activity (BA 1). They are organisms with a fully maintained, autonomous metabolism, the viability of which must be retained during transport, handling and storage operations. Living plants have high water contents of at least > 30% and thus belong in water content class 3 (WCC 3).

Type of cargo	Optimum travel temperature in °C	Humidity in %	Recommended transport temperature in °C	Max. duration of transport in d
Tree nursery products (cuttings and seedlings)	-1.1 - 4.4	90 - 95	0.6 - 4.4	21 - 180
Chrysanthemums	7.2 - 15.0	90 - 95	1.1 - 2.2	21 - 42
Gladioli	2.2	90 - 95	2.2 - 10.0	42 - 56
Carnations	0.0	90 - 95	1.1 - 2.2	21 - 28
Roses	0.0	90 - 95	1.1 - 4.4	4 - 14
Pot plants	-2.8 - 18.0	90 - 95	1.1 - 18.3	14 - 360

Table 15: Transport climate for living plants [28]

Transport temperatures for living plants are sometimes close to 0°C (see Table 15). In contrast, transport temperatures for flower bulbs, for example, are far above freezing point as they may be highly susceptible to chilling damage (see Table 16).

Type of cargo	Temperature in °C	Humidity in %	Duration of storage in m
Asphodel	5 - 9	75	
Dahlias	7 - 10	75	6 - 7
Freesias	12 - 15	75	4 - 6
Gladioli	1.6	75	7 - 8
Hyacinths	12 - 16	75	4 - 6
Iris	9.0		
Crocus	9.0		
Lilies	1.6	75	6 - 8
Narcissi	12.5 - 16	75	4 - 6
Snowdrops	12 - 13	75	4 - 6
Tulips	10 - 16	75	3 - 6

Table 16: Transport climate for flower bulbs [28]

Living plants require particular temperature, humidity/moisture and ventilation conditions (SC VII). Their respiration processes are specifically controlled by maintaining a "dormancy temperature". Oxygen must be supplied and harmful gases (carbon dioxide, ethylene) removed.

Refrigerated containers with a fresh air supply and CA containers are the most suitable for temperature-controlled container transport.

Transport instructions and damage
On the one hand, living plants must be protected from wetting, rain, condensation, container sweat and, during container packing, plants wrapped in sacking must be inspected for moisture damage as mold growth, rot and premature sprouting are otherwise possible. On the other hand, living plants have a tendency to dry out easily. It is thus absolutely essential to provide particular protection for plant roots. Travel temperatures depend on the plant species and must be specified by the shipper. Relative humidity should be 90 - 95%. Using refrigerated containers may result in drying-out of the cargo. Refrigerated containers which can supply humidified air should therefore be used. Flower bulbs require a rel. humidity of only 75%. Living plants are highly sensitive to ethylene: ethylene, like carbon dioxide, can bring about premature sprouting, and plants should thus never be stowed together in the same container with cargoes of fruit. CO_2 content should not exceed 0.1 vol%.

A supply of fresh air must be provided in order to prevent any build-up of carbon dioxide and ethylene. Plants, especially herbaceous perennials and shrubs with tender tip growth, such as privet, suffer from heat and sweat if inadequate ventilation is provided in transit. Overheating causes foliage to die.

Living plants may bring plant diseases/pests into the container which may infest simultaneously or subsequently transported cargoes or be released into other ports. A certificate of origin and phytosanitary certificate from the exporting country are required. Rats and mice may also be brought on board with the plants. If inspection by the phytosanitary authorities at the destination reveals that the cargo is infested by certain pests, the refrigerated container must be thoroughly cleaned after unpacking.

16.4 Meat/fish

Characteristics and fitness for container transport
Meat consists of skeletal muscle tissue, including fatty, connective and bone tissue, originating from slaughtered, skinned and gutted animals. Frequently transported types of meat are: cattle, pigs, calves, sheep and lambs. Meat is transported unpackaged or heat-sealed in plastic film or sewn into stockinette. Vacuum packaging is usual in particular for relatively small cuts of meat, such as steaks, minced meat etc.. Chilled meat is also described as fresh meat because, when correctly chilled, it retains the characteristics of fresh meat (see Figs. 108, 109).

Figure 108: Chilled beef: this beef has been stored at excessively low temperatures. Depending upon the receiver, this will result, at best, in depreciation of 20% and, at worst, the meat will have to be frozen with consequent depreciation of 40-50%;
Photo: Förster/Ahrens [12]

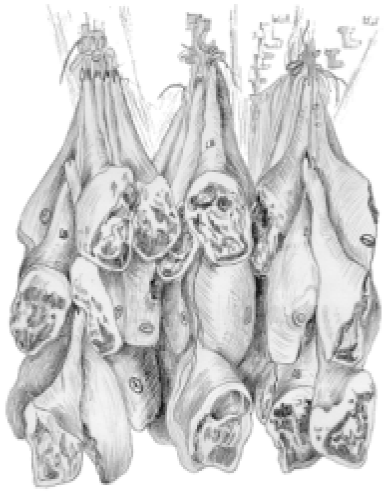


Figure 109: Chilled meat hanging from hooks in a container; stacking may cause loss of juices.

Fish is more highly perishable than meat. This high perishability is attributable to the protein-decomposing enzymes which are still active at low temperatures and the large proportion of psychrophilic microorganisms associated with fish. Flash-frozen fish (which is the best quality as there are no crystals within the cells) are heat-sealed in strong plastic film and packaged in hard board cartons. Fish is often frozen in blocks with water and packed into containers (see Fig. 110).

Figure 110:
Fish in blocks: to provide protection from freezer burn (drying-out of the frozen fish) and to facilitate handling, fish is flash-frozen in blocks with water. The portions broken away from the lower blocks in the right-hand stack are attributable to rough handling rather than thawing.
Photo: Förster/Ahrens [12]

Meat/fish are goods displaying 3rd order biotic activity (BA 3), in which respiration processes are suspended but in which biochemical, microbial and other decomposition processes still proceed.

Meat/fish have a high water content (50 - 75%) and thus belong in water content class 3 (WCC 3).

While fruit and vegetables are naturally resistant to microorganisms and infestation is usually initiated by mechanical damage, the decomposition activity of microorganisms in meat/fish begins as soon as rigor mortis subsides (see Table 17).

	Fruit/vegetables	**Meat/fish**
1. Cell walls	Cell walls consist of cellulose and are thus robust	Cell walls consist of proteins and are thus not very strong
2. Water content	Goods with a high water content (WC > 90%). WCC 3	
3. Respiration processes	Living organs in which respiration processes predominate - 2nd order biotic activity. BA2	Goods in which respiration processes are suspended, but in which decomposition processes still proceed - 3rd order biotic activity. BA 3
4. Viability	Maintenance of viability balanced against reduction of respiration ("dormancy temperatures")	Dead tissue, cells dead
5. Refrigeration temperatures	Refrigeration temperatures for fruit must be several degrees above freezing point, as there is a risk of chilling damage	Refrigeration temperatures may be very close to freezing point. Chilling damage may, for example, take the form of freezer burn

6. Ripening ability	Ripening ability lost if overcooled	No ability to ripen
7. Resistance to microorganisms	Naturally resistant to microorganisms. Infestation usually occurs only after mechanical damage.	No natural resistance to microorganisms. Decomposition begins once rigor mortis subsides, in the case of fish due to accompanying psychrophilic bacteria

Table 17: Comparison of chilled goods of vegetable and animal origin

As highly perishable foodstuffs, meat/fish require particular temperature, humidity/moisture and ventilation conditions (SC VII). Due to their low biotic activity, they generate no heat within the cargo and thus also do not require a supply of fresh air. Meat/fish must be packed in the container when frozen. The only heat which has to be removed from this frozen cargo block is that originating from outside. It is thus sufficient to circulate cold air around the outside of the cargo block.

Refrigerated containers are suitable for temperature-controlled container transport. Very highly perishable tuna has recently begun to be transported in special low temperature refrigerated containers which are capable of maintaining transport temperatures of as low as -60°C (see Section 15.3.1.3).

Transport instructions and damage
Meat and fish are highly perishable due to their high protein and water content and their fat content and postmortem biochemical and microbiological changes make them unfit for consumption.

Autolysis (self-digestion) may be caused by enzymes within the meat and takes the form of "putrefaction" resulting in softening and greenish discoloration of the meat and a foul odor due to the formation of hydrogen sulfide (H_2S).

One type of bacterial spoilage which may be mentioned is the psychrophilic spoilage which is caused by the psychrophilic bacteria accompanying the fish and by bacteria in the refrigerated container atmosphere. Such organisms form coffee-brown to yellowish colonies on the surface of the meat/fish and, being fluorescent or flavobacteria, may also luminesce. This type of spoilage is caused by unhygienic slaughtering and the bacteria continue to grow at chilling temperatures.

Molds may also colonize poorly cleaned areas, with the abdominal muscles, shoulder blades and neck area being at particular risk in meat. Affected meat develops a musty odor.

Fatty meat, such as pork, and oily fish have a tendency to become rancid due to oxidation of the unsaturated fatty acids and the plastic material used in packaging should thus provide the best possible oxygen barrier.

Chilled meat is transported at temperatures close to freezing point.
The aims of chilling are as follows:

- to inhibit autolytic changes
- to prevent spoilage due to microorganisms
- to retain the freshly slaughtered state of the meat

No ice crystals should be visible on the surface of the meat. The maximum travel temperature for fresh meat is 0°C. Even partial freezing of chilled meat results in loss. The high content of unfrozen water means that enzymes and microorganisms can remain active. Chilled meat has a storage life of only a few weeks.

The use of "protective atmospheres", such as CO_2, has extended the range of chilled meat transport operations, e.g. from Australia to Europe. A CO_2 content of approx. 10 - 12% suppresses surface growth of aerobic molds and ensures a 4 - 5 fold reduction in the rate of development of aerobic spoilage bacteria. A higher CO_2 content, however, results in more rapid browning of the meat and greying of the fat.

Sides of beef are, for example, transported suspended as the pressure caused by stacking would result in loss of meat juices (see Fig. 109). Relative humidity should be 80 - 85%; lower values increase weight loss and drying-out, while higher values increase the activity of microorganisms.

Frozen meat/fish
Frozen meat/fish is flash-frozen to a core temperature of -18°C - -27°C and strict compliance with the freezing chain must be ensured during transport. Temperature variations of > 1°C result in recrystallization. The minute ice crystals formed within the cells during the flash-freezing process could then grow into large crystals. Variations in temperature are associated with continual slight thawing and refreezing. Since small ice crystals have a higher vapor pressure than larger ones, they will melt more rapidly when the temperature rises, while on cooling the same effect means that the water is preferentially deposited as ice on the larger ice crystals. The large ice crystals rupture the cell walls, as a result of which considerable drip loss occurs on subsequent thawing of the meat/fish. The meat becomes dried out and its quality is impaired.

When packing refrigerated containers, it must be checked whether thawing has occurred. Clear signs of thawing are: discolored protective coverings, distortion and dark muscle tissue color or formation of "snow" inside the plastic bags.

With frozen meat/fish, relative humidity may be 90 - 95% because the low temperatures very largely suppress

microbial growth and only slight weight loss occurs. Excessively low humidities result in drying-out and, ultimately, freezer burn, which is irreversible (see Figs. 110, 111). However, at subzero temperatures, humidity/moisture can only be changed structurally by means of the size of the evaporator surface in the container's refrigeration unit. Film packaging, compact stowage, little free space above the cargo (only pack up to the red line), avoidance of thermal bridging (intact containers) and precise compliance with temperature prevent the goods from drying out during transport.

Figure 111:
Freezer burn on beef tongues
The thickness of
the frost layer may
subsequently be used
to determine the
duration of storage.
Photo: Nielsen [24]

Frozen meat splinters like wood, so dropping and impact result in breakage. It is accordingly sensitive to other mechanical stresses, e.g. slipping due to poor stowage, during transport and handling operations.

Table 18 shows the temperatures for frozen animal products, which are generally lower than -18°C, at which the majority of the cytosol is frozen.

Cargo type	**Temperature in °C**
Eel	-20
Butter	-18 - -15
Shelled egg	-20 - -15
Fat	-20 - -15
Fish	-30 - -17
Fish oil	-30 - -20
Meat, mutton	-18 - -15
Meat, beef	-23 - -20
Meat, pork	-18 - -15
Poultry	-25 - -18
Herring	-30 - -22
Spiny lobster tails	-15
Horse meat	-12
Whale meat	< -15

Table 18: Temperature conditions for frozen storage of animal products during transport; Becker [5]

Damaged cartons should not be packed in the container as weight loss combined with degradation of quality due to freezer burn may occur. Fish must, on principle, be stowed alone in a refrigerated container because odor tainting must always be expected.

The sides of a refrigerated container are corrugated, so that the air can flow properly around the cargo block. Care must be taken during packing that all the cartons are stowed in such a way that they cannot slip into the corrugations even in rough seas. It must be ensured that the container is at the specified subzero temperature before packing begins.

17 Hygroscopic foodstuffs

17.1 Characteristics and fitness for container transport

Hygroscopic foodstuffs are goods with a low water content (WC > 1.5 - < 30%) of water content class 2 (WCC 2), from which water has been removed by natural or artificial drying, thereby increasing their storage life and thus fitness for container transport. They interact with the water vapor content of the ambient air, i.e. they release water vapor or absorb water vapor until they are at equilibrium with the water vapor content of the ambient air (see Section 10.2.2). They include the majority of foodstuffs and semiluxury items, such as cereals, oil-bearing seeds/fruits, dried fruit, spices, coffee, cocoa, tobacco and tea. Animal raw materials and natural fibers also belong to this group, however. Their adsorption isotherms form a continuous, generally S-shaped, curve.

Hygroscopic goods do, however, also include goods which have low water contents (WC > 0 to < 1.5%) i.e. which belong to water content class 1 (WCC 1). They are of crystalline or pulverulent structure, e.g. sugar, salts or citrus powder. Their adsorption isotherms are characterized by discontinuities (see Fig. 5 in Section 10.2.7).

Some hygroscopic foodstuffs are goods displaying 2nd order biotic activity (BA 2), i.e. living organs which continue to respire but which lack any supply of new nutrients due to separation from the parent plant, e.g. cereals, oil-bearing seeds. Some are goods displaying 3rd order biotic activity (BA 3), such as dried fruit.

Crystalline and pulverulent foodstuffs are goods displaying 3rd order biotic activity (BA 3), in which respiration is suspended but in which biochemical, microbial and other decomposition processes still proceed.

Hygroscopic foodstuffs require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI) (storage climate conditions). Undesirable changes occur as a function of relative humidity and temperature, in particular due to dampening (mold, rot, mildew stains, fermentation, deliquescence, self-heating, loss of crispness, mustiness, loss of aroma, syrup formation) or to desiccation (solidification, jamming/caking, fragmentation, drying-out). The critical water content is the most significant value, being that which, when exceeded, results in changes in quality. The foodstuffs in this group do not have any particular requirements as to ventilation conditions, if they are container dry.

In order correctly to set the necessary parameters, such as temperature and relative humidity, as a function of route, duration of voyage, season and period of time the goods spend in the container, ventilation may be necessary, i.e. the decision has to be made as to whether to use a standard container or a ventilated container. Most hygroscopic foodstuffs may be transported in standard containers, provided certain restrictions are taken into account.

17.2 Cereals

Characteristics and fitness for container transport
The term "cereals" covers the grain fruits of cultivated grasses (wheat, rice, corn, barley, millet, oats (Fig. 112), rye etc.). As a rule, cereals are transported worldwide in bulk carriers, for instance from the USA, Canada, Argentina, India, Indonesia and Australia. Seed and malt etc. are also transported by container.

Figure 112: Oats;
Photo: U. Scharnow

With a water content of 11.5 - 15% (see Tab. 1), cereals belong the water content class 2 (WCC 2). The sorption isotherms exhibit a continuous S-shaped profile. As living organs, cereals belong to the category of goods displaying 2nd order biotic activity (BA 2). Cereals require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI). Cereals do not have any particular requirements as to ventilation conditions, if they are introduced into the container in a container dry state and the temperatures and relative humidities can be kept correspondingly low.

Constituents	Rye, wheat	Rice	Corn
Carbohydrates	68 - 69	up to 80	70
Protein	11 - 12	5 - 7	10.5
Fat	2	approx. 1	4.5
Raw fiber	2	0.3	2.5
Ash	1.5 - 2	0.5	1.5
Water	13 - 15	> 14	11.5

Table 19: Chemical composition of major types of cereal in % [28]

Seed cereal and malt are transported in bulk containers with appropriate predrying to approx. 12 - 13%. Should standard containers be provided, it is advisable to suspend liner bags of plastic fabric with integral nonwoven fabric in the containers to catch sweat.

The cargo is kept away from the container doors by four rectangular bars, which fit into the container's last pair of corrugations. Once the container has been loaded, the liner bag is closed by means of straps. The container is unpacked by cutting the liner bag open at the bottom and tipping the container.

Bagged seed and malt in particular are also transported in standard containers.

Ventilated containers are favorable, since they may be actively ventilated from outside in order to dissipate moisture and heat. They have to be loaded below deck, in order to allow ventilation to work effectively. This is also true of standard containers: on deck, extreme temperature gradients may occur, especially during winter in the northern hemisphere, which may lead to container sweat or cargo sweat.

The structure and chemical composition of the grain vary little between the different types of cereal (see Table 19). As far as structure is concerned, three constituents of the cereal grain are worthy of further consideration:

- its cracked husk, which gives the grain a greatly increased surface area relative to its mass. This allows the cereal grain to enter into an active exchange of materials with its environment (moisture, odor).
- the endosperm, which constitutes the main component of the grain.
- the embryo (Fig. 113)

In rice, the silver skin is also important, being removed to a greater or lesser extent by appropriate processing stages.

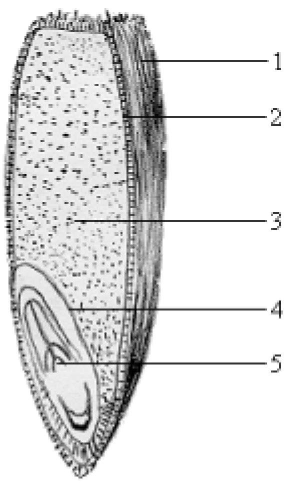


Figure 113: Longitudinal section through a rye grain

1 - multilayer husk and seed coat
2 - aleurone layer
3 - endosperm
4 - scutellum
5 - embryo

Hygroscopicity

Carbohydrates, especially starch, are the main constituent of a cereal grain. However, when it comes to transport in bulk, standard and ventilated containers, it is the water content that is important. Although, at 11.5 - 15%, the water content is low compared to that of fruit and vegetables, it still plays a considerable part in the respiration processes of the seed cereal. When transporting cereals, it must be remembered that they are living, vegetable organisms whose ability to germinate must be retained. The hygroscopic properties of cereals were described in Section 10.2.2. Fig. 114 shows the most important sorption isotherms for cereals.

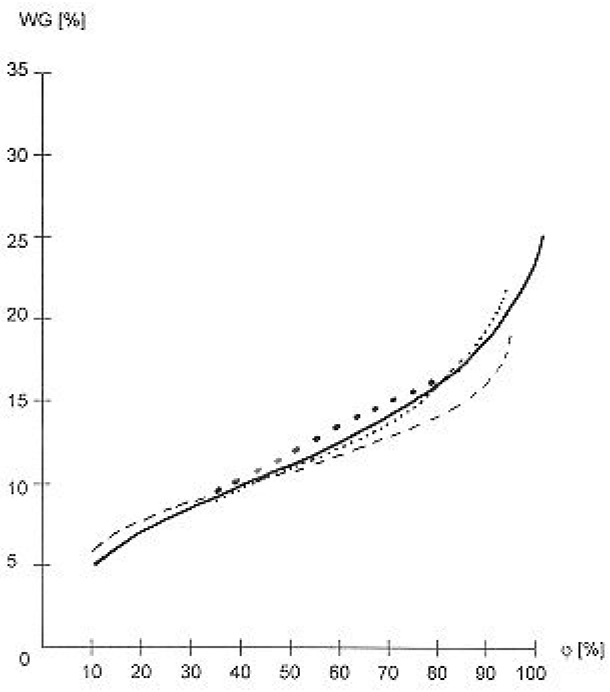


Figure 114: Sorption isotherms for cereals

— rye (20°C)
--- rice, hulled (25°C)
···· wheat (20°C)
••• corn (20°C)

Respiration of the ripe cereal grain
The influence of temperature and water content on the respiration intensity of the cereal grain is illustrated in Fig. 115.

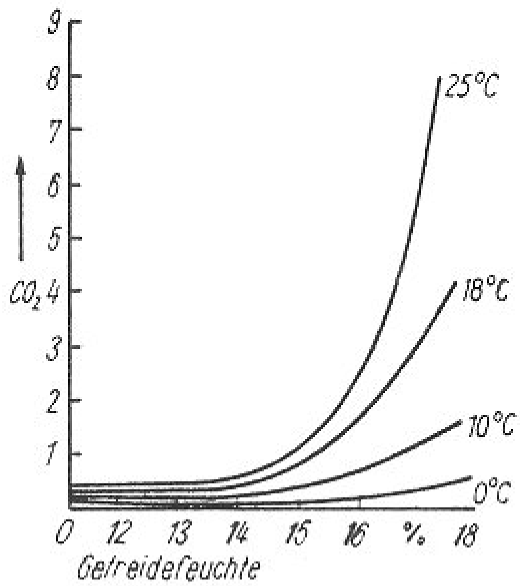


Figure 115: Respiration intensity of wheat as a function of humidity/moisture and temperature (development of mg of CO_2 per 100 g of dry wheat solids over 24 hours); Herrmann [17]

Curves 1 - 4 show the respiration intensity of wheat as a function of storage temperature and water content. The following conclusions may be drawn from this illustration:

- At a low water content, the intensity of respiration is low at all temperatures. Even at temperatures of 25°C, respiration intensity is low at water contents of up to 13%. Cereal having a water content of less than 13% is thus deemed to be container dry. With these goods there need be no reservations about suspending ventilation. In the case of container dry cereals, the risk of self-heating is low, since the drier grains absorb the water content from the moister ones.

- At water contents of 14% upwards, respiration intensity begins to increase; at temperatures of 0°C and 10°C respiration remains slight. The respiration of cereal may therefore largely be inhibited by low transport temperatures.

- At water contents > 15%, respiration increases rapidly. If, in addition to the high water content, high temperatures also occur, respiration is further intensified, as shown by the respiration curves for 18°C and 25°C. Rice reacts even more sensitively to moisture because of its higher water content (see Table 19).

- The increase in respiration results not only in the formation of carbon dioxide and moisture but also in increased evolution of heat. Moisture and heat in turn promote the activity of the respiratory enzymes, which bring about more rapid respiration, as a result of which this increase in cereal respiration may result in self-heating.

Transport instructions
After harvesting, cereals usually undergo further post-ripening, which consists of the high molecular weight substances congregating further with water being expelled (syneresis). As the surface of the cereal then becomes damp because of the elevated water content, this is described as "sweating". In this state, the cereal is highly susceptible to mold and must not as yet be transported. However, if the water content of the cereal is low (< 13%), proper storage allows the sweat moisture to be absorbed by the air without the risk of mold growth. This sweating process lasts for approximately one to two months.

Composition of the ambient air
The excretion of carbon dioxide by respiring cereals is important from various standpoints. If relatively large quantities of carbon dioxide accumulate in the hold, the respiratory activity of the cereal will drop. In the case of cereal which is container dry, air with an increased carbon dioxide content does not have a negative impact on the quality of the cargo, indeed mold growth is inhibited.

Odor
Cereals are sensitive to the absorption of foreign odors. The considerable absorption capacity of the cereal grain results from its rough surface and the individual shells of the husk and seed coat, which communicate with the external air through cracks. One metric ton of rye has a total surface area of 64,000 m². The resultant large overall surface area explains the elevated odor sensitivity of cereal grains. Gases and aroma substances, such as sulfur dioxide, phenol and kerosene (strong smelling chemicals), are readily absorbed by the cereal. For this reason, containers must be completely odor-free. On the other hand, excessively wet rice, in particular, may spread a penetrating odor.

Damage
The evolution of heat and moisture by the seed cereal has the following consequences:

- The seed cereal may become musty, ferment and turn sour: when moisture levels are excessive, the cereal grains agglomerate and become caked.
- Risk of mold development; rice and corn are at particular risk from mold.
- Risk that seed cereal may lose the ability to germinate. However, if seed cereal is transported in bulk containers at relatively high water contents, i.e. for example wheat with water contents > 14%, the seed cereal must be expected to change over from aerobic to anaerobic respiration due to the build-up of carbon dioxide, which means, among other things, that lactic acid bacteria, which are able to tolerate an anaerobic environment, can also develop. The fermentation products carbon dioxide, lactic acid and alcohol have an impact on the seed cereal, since these fermentation products have a toxic effect on the grain germ, and the seed loses its ability to germinate if stored in an oxygen-depleted environment.
- Risk of premature cereal germination, which constitutes serious damage in the case of seed.
- Risk of infestation by animal pests, which, at favorable temperatures, may develop well even at water contents < 14%.
- The evolution of moisture and heat by microorganisms and animal pests due to respiration, which may accelerate self-heating of the cereals (see Section 13.12).
- Risk of self-heating. Rice and corn have a particular tendency to undergo self-heating.
- Risk of rancidity. Due to its relatively high water content, rice in particular has a tendency to become rancid owing to the formation of free fatty acids; this risk is particularly great in the case of brown rice because of the oil-containing silver skin.
- When packing containers at the place of departure, it must be remembered that hygroscopic seed cereal can reabsorb moisture during storage in moist, tropical air. In areas with dry and rainy seasons, the transport date must be noted.

To counter all these risks, seed cereal must not become either damp or warm during transport.

The seed, especially rye seed, must be carefully cleaned due to infestation with toxic ergot (see Figs. 116, 117).

Figure 116: Ears of rye with ergot;
Photo: U. Scharnow

Figure 117: Ears of rye with ergot;
Photo: U. Scharnow

17.3 Oil-bearing seeds/fruits

Characteristics and fitness for container transport

Like cereals, oil-bearing seeds/fruits, for example cottonseed, rapeseed (see Fig. 118), olives (see Fig. 119), sunflower seeds and palm kernels are vegetable foodstuffs with a low water content and thus belong to water content class 2 (WCC 2). As living organs in which respiration processes predominate, because their supply of new nutrients has been cut off by separation from the parent plant, oil-bearing seeds/fruits are goods which display 2nd order biotic activity (BA 2).

Figure 118: Rapeseed;
Photo: U. Scharnow

Figure 119: Olive tree branch with olives

They differ from cereals above all in their high oil content, which may vary within broad limits. Oil-bearing seeds/fruits are used to obtain sweet oils (c.f. Section 18.1). Since shell fruit (nut types), such as Brazil nuts, hazelnuts and walnuts, place the same requirements on transport, handling and storage processes as oil-bearing seeds/fruits due to their similar properties, in particular with regard to their high oil content, these will also be looked at here.

Sunflower seeds and peanuts stand out due to their particularly high oil content; the oil content of babassu kernels, hazelnuts, Brazil nuts, pecan nuts etc. is higher than 60% (see Table 20).

No.	**Product name**	**Oil content in %**	**Water content in %**
1	Babassu kernels	66.0 - 69.0	5.0 - 13.0
2	Cottonseed	18.0 - 26.0	7.0 - 12.0
3	Betelnuts	20.0 - 36.0	
4	Boleko nuts	20.0 - 36.0	
5	Beech nuts, shelled	27.0 - 44.09	9.0 - 14.0
6	Cashew nuts	45.0 - 50.0	5.0
7	Chufa nuts (earth almonds)	21.0 - 23.6	6.4 - 11.8
8	Peanuts	20.0 - 60.0	10.0
9	Gall nuts	62.0	
10	Hempseed	30.0 - 35.0	10.0
11	Hazelnuts	50.0 - 63.0	6.0
12	Hazelnut kernels	62.0 - 69.0	7.0
13	Charlock seeds	26.0	10.0
14	Illipe nuts	50.0 - 55.0	8.0 - 10.0
15	Cacao seeds, decorticated	50.0 - 60.0	
16	Kapok seed	22.6 - 25.0	7.4
17	Coconuts	30.0 - 40.0	42.0 - 48.0
18	Desiccated coconut	55.0 - 72.0	5.0 - 6.0
19	Cola nuts	1.4 - 2.0	12.0
20	Pumpkin seeds, decorticated	45.0	5.9
21	Pumpkin seeds, unshelled	38.6	7.3
22	Linseed	30.0 - 47.8	10.5
23	Camelina seed	31.0 - 35.0	8.6 - 9.7
24	Lime tree seeds	8.2	12.0
25	Lupin seeds	10.0	
26	Almonds	53.0 - 59.0	6.0
27	Corn germ, top grade	30.0 - 48.0	4.14
28	Poppy seed	45.0 - 50.0	10.0
29	Mowrah seed	50.0 - 52.0	5.0 - 10.0
30	Niger seed	40.0 - 50.0	6.2
31	Oiticica seed	60.0 - 63.0	3.0 - 5.0
32	Marrow seeds, decorticated	50.0	3.8 - 5.1
33	Oil palm, flesh	65.0 - 72.0	
34	Arugula	28.3	10.1
35	Olives, green	15.3	68.0
36	Olives, black	15.0 - 31.0	52.0
37	Olives, flesh	40.0 - 60.0	28.0
38	Olives, kernels	12.0 - 15.0	8.0
39	Palm kernels	40.0 - 60.0	4.0 - 8.0
40	Brazil nuts	50.0 - 68.0	5.0

41	Pecan nuts	45.0 - 60.0	
42	Perilla seed	44.0	8.0
43	Plum kernels, decorticated	41.2	12.6
44	Pine kernels	50.0	23.0
45	Pistachio kernels	50.0	23.0
46	Radish seeds	35.0 - 40.0	6.3
47	Rapeseed	38.0 - 42.0	10.0 - 12.0
48	Rice germ	19.8	
49	Castor beans	40.0 - 60.0	4.0 - 8.0
50	Rye germ	10.0 - 12.0	6.0 - 9.0
51	Horse-chestnuts	7.6	5.5
52	Turnip rape	40.8	8.0
53	Safflower seed	25.0 - 35.0	70.0
54	Mustard seeds	15.0 - 35.0	5.0 - 9.0
55	Sesame seed	42.0 - 50.0	5.0 - 13.0
56	Shea nuts	46.0 - 48.0	5.0 - 8.0
57	Soybeans	13.0 - 24.0	8.0 - 10.0
58	Sunflower seeds	19.0 - 56.0	7.0
59	Tobacco seed	35.0 - 41.0	6.0 - 12.0
60	Fir seed	25.0 - 30.0	
61	Tomato seeds	18.0 - 23.0	
62	Grapeseed, dried	16.0 - 18.0	7.8 - 10.5
63	Walnuts	50.0 - 65.0	2.0 - 3.0
64	Wheat germ	7.0 - 12.0	7.5 - 8.8
65	Sugar beet seeds	18.5	5.1

Table 20: Oil and water content of oil-bearing seeds/fruits [28]

While in cereals carbohydrates predominate and protein and cellulose occur in relatively small quantities, in oil-bearing seeds/fruits protein (raw protein) and cellulose (raw fiber) occur in larger quantities. Sunflower seeds and soya beans stand out in particular due to their high raw fiber content.

Undesirable changes, such as mold and mustiness but especially self-heating and possibly even spontaneous combustion occur as a function of relative humidity and temperature, in particular due to dampening. Oil-bearing seeds/fruits therefore require particular temperature, humidity/moisture and ventilation conditions (SC VII).

Oil-bearing seeds/fruits require ventilated containers in order to dissipate the heat and water vapor formed by self-heating and to be able to receive a supply of fresh air. Protection against solar radiation and stowage below deck are advisable. Due to their sensitivity to moisture and their tendency to release water vapor, oil-bearing seeds/fruits are best transported in a ventilated container.

Hygroscopicity
Due to their oil content, oil-bearing seeds/fruits exhibit some peculiarities with regard to hygroscopicity. For instance, the sorption isotherms in Fig. 120 show that, due to the high oil content, the water content for an equilibrium moisture content of 75% (mold growth threshold) is substantially lower than in cereals.

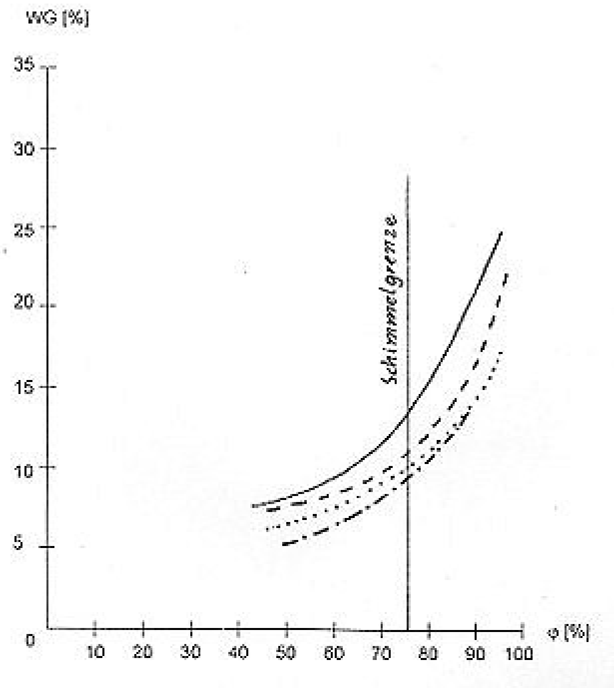


Figure 120: Sorption isotherms for oil-bearing seeds/fruits

— Soybeans
--- Cottonseed
··· Linseed/sunflower seeds
-·- Mustard seed

The oil itself does not exhibit any hygroscopicity. Water is bound above all by minerals and protein, as well as by capillary condensation. Therefore, different equilibrium moisture contents may occur for the same type of oil-bearing seed/fruit with the same water content, depending on its oil content. The higher the oil content of an oil-bearing seed/fruit, the lower the hygroscopicity and the lower the required water contents for storage stability.

Fat decomposition in oil-bearing seeds/fruits
The oil builds up in the seeds or fruit flesh as a nutrient reserve and is stored in them in fine droplets. Fat is a chemical compound consisting of glycerol and fatty acids.

Fat decomposition in oil-bearing seeds/fruits leads to the risk of self-heating and, often, to a cargo fire. Fat decomposition may proceed in two ways:

- by hydrolytic/enzymatic fat cleavage (see Section 13.6.1)
- by oxidative fat cleavage (see Section 13.6.2)

Hydrolytic/enzymatic fat cleavage is caused primarily by moisture.

The fat-cleaving enzymes (lipases) are activated by a relatively high water content and light and heat may speed up the process.

The extent to which hydrolytic/enzymatic fat cleavage is determined by water content is clear from Fig. 121. According to the sorption isotherm, the critical water content for cottonseed, for example, is 10%. At water contents of 9.5 - 11.5% and a storage temperature of 15.5°C, hydrolytic/enzymatic fat cleavage and thus the tendency of cottonseed to turn rancid (rancidity) is extremely slight. This results in a long storage life. The free fatty acid content starts to increase at a water content as low as 13.4%. At a high water content of 15.2 - 17%, the free fatty acid content increases so quickly that only short transport or storage times are possible.

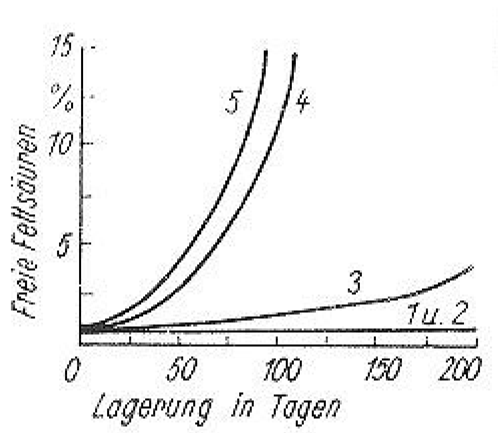


Figure 121:
Free fatty acid content as a function of storage time at 15.5°C for cottonseed with different moisture contents.
Moisture content of cottonseed at

1 - 9.5%
2 - 11.5%
3 - 13.4%
4 - 15.2%
5 - 17.0%

Herrmann [17]

When analyzing Fig. 121, it should be noted that the storage temperature of 15.5°C is still relatively low. When transporting oil-bearing seeds/fruits from the tropics and subtropics, substantially higher temperatures must be expected, which accelerate hydrolytic/enzymatic fat cleavage. The free fatty acids formed are consumed by respiration processes in the oil-bearing seeds/fruits to form carbon dioxide and water, a process which is associated with considerable evolution of heat. Self-heating of oil-bearing seeds/fruits is an extremely vigorous process. Self-heating on exposure to moisture, which may lead ultimately to cargo fire, proceeds in several stages:

- the general biological phase
- the microbiologically particularly active phase
- the thermophilic decomposition phase
- the pyrophoric gas phase (see detailed description in Section 13.6.1)

The self-heating of oil-bearing seeds/fruits requires only a small seat of moisture. Due to its strong tendency towards self-heating, sunflower seed is considered particularly hazardous. The reason for this is its particularly high oil content (up to approx. 56%), coupled with its high raw fiber content (25.6%)

Fresh oil-bearing seeds/fruits with a high water content, especially fresh peanuts, tend towards rapid self-heating and may ignite. Self-heating of oil-bearing seeds/fruits leads to a reduction in the quality of this product (rancid odor and taste) and also has a qualitative and quantitative effect on oil yield. The heat arising through self-heating of the cargo must be dissipated as quickly as possible by ventilation.

Hydrolytic/enzymatic fat cleavage and respiration may be limited by low temperatures; however, this may only be affected to a limited degree or not at all during container transport. It is therefore important to ensure storage stability by complying with the limit values for the water content.

Peanuts, babassu kernels and copra, when fresh and not warehoused, are at particular risk.

Odor
Oil-bearing seeds/fruits display different behaviors with regard to odor compatibility: some oil-bearing seeds/fruits can have a disadvantageous effect on other goods due to the odor they release (babassu kernels, copra), while others are themselves odorless, so meaning that they can be stowed together with other goods (linseed, sesame seed, soybeans), and still other are themselves odorless but very sensitive to foreign odors (almonds). These different properties have to be taken into account when packing a container.

Contamination
As a result of the high oil content of the goods, dark fat spots often appear on the bags. This should be taken into account if they are to be loaded together with other goods.

Toxicity/Hazards to health
Intensive respiration may result in carbon dioxide concentrations which are hazardous to health and reduced oxygen content. In a container, the danger to health is averted by opening the container doors.

Insect infestation/Diseases
Insect infestation generally occurs during storage prior to packing of the container. When the container is being packed, infestation by pests such as grain moths, khapra beetles, flour beetles, mites, cockroaches, sawtoothed grain beetles, meal moths, dried fruit moths and rats and mice should therefore be looked for. A fumigation certificate may possibly be required.

The increased respiration of the oil-bearing seeds/fruits resulting from pest chewing damage leads to moist spots, which promote mold growth. Molds, such as Aspergillus flavus, produce the carcinogenic mold toxin aflatoxin.

17.4 Dried fruit

Characteristics and fitness for container transport
Dried fruits include all fruit types preserved by a drying process. Fruit intended for drying is harvested at the climacteric stage, when the juice and sugar content are at their maximum. Preserving by drying works on the principle that, by reducing the water content, the biochemical and microbiological processes which impair the quality of the dried fruit are restricted considerably. The main types of dried fruit transported in relatively large quantities are raisins, dates, figs and apricots (see Fig. 122). With a water content < 30%, dried fruit is an organic product with a low water content and thus belongs to water content class 2 (WCC 2) (see Table 21).

Type of dried fruit	Water content in %	Rel. humidity in %
Apples, dried	20 - 24	70 - 75
Apricots, dried	22 - 25	65 - 70
Pears, dried	22	65 - 75
Dates, dried	14 - 20	50 - 60
Figs, dried	18 - 30	60 - 65

Peaches, dried	20 - 23	70 - 73
Prunes	18 - < 20	60 - 70
Raisins	14 - 16	55 - 65
Sultanas	17 - 19	60

Table 21: Water contents and optimum relative humidities for dried fruit [28]

Figure 122: Dried fruit;
Photo: U. Scharnow

1 - apple ring
2 - prune
3 - pear
4 - pineapple
5 - apricot

Dried fruits are strongly hygroscopic. Their sorption isotherms rise steeply. The respiration processes of the dried fruit are suspended by drying; it is therefore a product displaying 3rd order biotic activity (BA 3).

Dried fruit requires particular temperature, humidity/moisture and possibly ventilation conditions (SC VI) (storage climate conditions). Dried fruit does not have any particular requirements as to ventilation conditions, if it is container dry. Dried fruit is transported in standard containers, subject to compliance with upper and lower limits for the water content of goods and packaging. Ventilated containers would be best, in order to achieve better temperature and moisture conditions.

Transport instructions and damage
Most of the changes suffered by dried fruit are associated with its hygroscopicity. The optimum water contents and associated equilibrium moisture contents are indicated in Table 21.

It is clear from this Table that the water contents are much higher than those of cereals and oil-bearing seeds/fruits; however these contents correspond to lower equilibrium moisture contents, which are often exceeded during transport. Given that heat and moisture are the primary causes of undesired changes (mold, fermentation, syrup formation, the coolest possible positions should be selected for containers carrying dried fruit or refrigerated containers should be used. If the relative humidity falls below the values indicated, the dried fruit becomes tough and hard and tends towards candying.

Packaging requirements
When palletizing dried fruit, care must be taken to ensure that the fruit's packaging can withstand the pallet stack pressure. Since the stack heights in a container are limited structurally, this may be achieved with standard packaging. If there are any doubts about stability, intermediate layers of boxboard may be used to improve it. If the fruit itself has to absorb the pressure, it tends to form syrup, especially in the lower layers. The syrup comes out of the fruit and may stick the entire packaging together.

Mold risk
The sorption isotherms for dried fruit (see Fig. 123) show that the equilibrium moisture contents are very low, being way below the optimum living conditions for molds (mold growth threshold at 75% relative humidity. Since relative humidity values of above 75% can occur in a standard container, dried fruit is in danger of developing mold. This may also occur of cartons, cases or bags have absorbed moisture from sweat, rain or seawater in containers which are not watertight. Mold growth is encouraged by high temperatures. Molds may form poisonous metabolic products (mycotoxins).

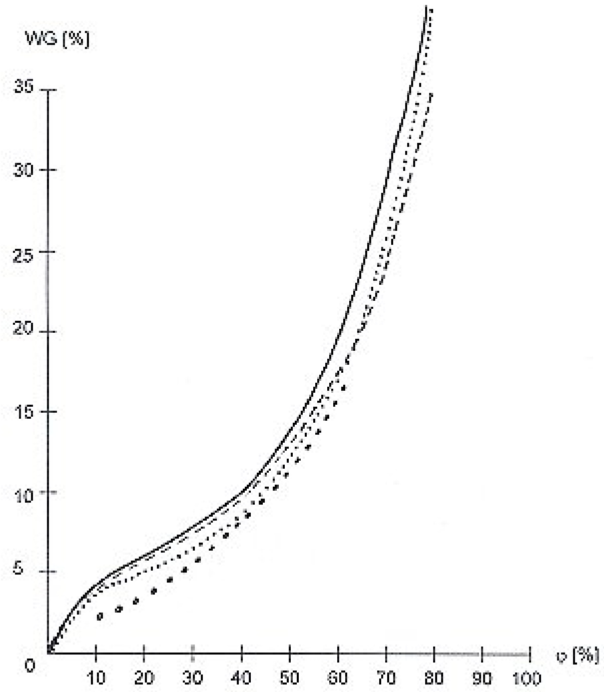


Figure 123: Sorption isotherms for dried fruit (20°C)

— plums, dried
--- sultanas, dried
···· apricots, dried
••• apples, dried.

Insect infestation/Diseases
Pests which may infest dried fruit include moths (e.g.dried fruit moth, almond moth, meal moth) and mites as well as some beetles (e.g. sap beetle, sawtoothed grain beetle, flour beetle. All soft-skinned dried fruits, in particular figs, sultanas, currants and apricots, are at great risk of mite infestation. Mite infestation is particularly dangerous because the consumption of mite-infested foodstuffs may lead to severe gastrointestinal conditions. Rats, mice or ants can also be a problem.

17.5 Spices

Characteristics and fitness for container transport
The term spice is used to refer to plant parts which serve to improve the odor and flavor of foods. Spices contain essential oils and other ingredients which have a strong seasoning action.

Exotic spices mainly originate in tropical and subtropical countries and are processed, cleaned, graded and carefully packaged for overseas dispatch in the countries where they are cultivated. In consumer countries, they are delivered to spice mills, where they are cleaned and graded again and sold in unground or ground form.

Spices are classified by the plant parts used:

- Fruit and seed spices (e.g. pepper, cardamom, nutmeg) (see Fig. 124)
- Bud and flower spices (cloves) (see Fig. 125)
- Bark spices (cinnamon, cassia) (see Fig. 126)
- Root spices (ginger, turmeric) (see Fig. 127)
- Leaf spices (bay leaf) (see Fig. 128)

Figure 124: Green pepper (fruit and seed spices); Photo: U. Scharnow

Figure 125: Cloves (bud and flower spices); Photo: U. Scharnow

Figure 126: Cassia (bark spices);
Photo: U. Scharnow

Figure 127: Ginger (root spices);
Photo: U. Scharnow

Figure 128: Bay leaf (leaf spices);
Photo: U. Scharnow

Spices are dried to preserve them for transport and storage. Other preservation methods are also used for some types. After drying, the water contents of the spices amount to 8 - 23% (see Table. 19). They are thus goods with a low water content and therefore belong to water content class 2 (WCC 2).

	Type of spice	Essential oil content	Fatty oil content	Water content
1.	**Fruit and seed spices**			
	Aniseed	2.0 - 6.0 (aniseed oil)		10 - 12
	Cayenne pepper, Chilies	0.5 (capsaicin)	11	8 - 12
	Fennel seed	5.0 - 6.5 (fenchone, anethole)		approx. 10
	Cardamom	3 - 8 (cardamom oil)	2	10 - 12
	Capsicum	10 - 13, of which 0.15 - 0.50 capsaicin		up to 13
	Coriander	0.4 - 1.8 (coriandrol)		max. 15
	Caraway	2.5 - 6 (caraway oil)	up to 12	14 - 15
	Mace	4 - 15 (myristicin)	>20 - 30	up to 10
	Nutmeg	6 - 10 (myristicin)	35 - 40 nutmeg butter	up to 9
	Pepper - black pepper	4.6 - 9.7 (piperine)	7	10 - 15

	Allspice	2 - 5 (allspice berry oil)	6 - 8	13 - 15
	Star anise	2 - 8 (anethole)	12.5	12
	Vanilla	1.5 - 3.0 (vanillin)		
2.	**Bud and flower spices**			
	Cloves	14 - 20 (eugenol)	7 - 10	11 - 23
	Saffron	0.4 - 1.3 (saffron-bitter)		9 - 10
3.	**Bark spices**			
	Cinnamon, cassia	1 - 3.5 (cinnamon oil)	7.8	12 - 15
4.	**Root spices**			
	Ginger	0.8 - 5 (gingerol)		max. 14
	Turmeric	1.5		14
5.	**Leaf spices**			
	Bay leaves	0.5 - 3.0 (cineole)		10 - 11

Table 22: Oil and water contents of spices in % [28]

Their sorption isotherms form a continuous, generally S-shaped curve (see Fig. 129).

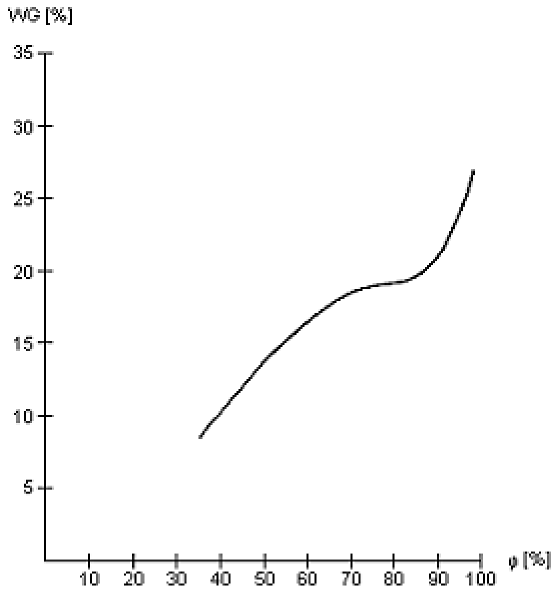


Figure 129: Sorption isotherm for pepper (20°C)

Drying interrupts the respiration processes. Spices are therefore goods which display 3rd order biotic activity (BA 3).

Spices require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI) (storage climate conditions). Spices do not have any particular requirements as to ventilation conditions, if they are container dry.

Spices are transported in standard containers. Pepper and cloves present problems and for them ventilated containers (coffee containers) are more suitable, allowing dissipation of water vapor.

Packaging
Spices are very high-quality products and have to be treated with great care during transport. Packaging should provide protection in particular against exposure to moisture, mechanical damage, loss of aroma and infestation by animal pests. Jute packaging does not provide this protection, and indeed even wooden cases do not protect against insect infestation. Since all spices are more or less hygroscopic, protection from moisture is the primary consideration when selecting packaging, since moisture could lead to fermentation or mold growth. Both would permanently impair quality (aroma and flavor). The second most important consideration is protection against loss of aroma. For these reasons, very widespread use is currently made of cartons, sometimes with multiple layers of film packaging. When this virtually water vapor-tight packaging it used, it is especially important for the spices to be "container dry". During transport from hot to cold regions, the mold growth threshold (75% rel. humidity) must not be exceeded. Condensation must be prevented. If the spices do not leave the country of production suitably dry, they must be given the possibility to release moisture during the voyage, so entailing water vapor-permeable packaging. This is achieved, among other ways, by perforated film packaging and by packing in ventilated containers. Plywood chests with composite films are likewise used as packaging for spices. The composite film ensures water vapor- and aroma-impermeability and the plywood chest provides the necessary mechanical loading capacity. Despite the aroma-tightness of the packaging, it is inadvisable, and in some cases impossible, to load different spices together.

Hygroscopicity
Spices are hygroscopic goods which interact with the moisture in the air. They may on the one hand be moisture sensitive (e.g. cloves, cinnamon, bay leaves) and on the other themselves release water vapor, e.g. pepper.
The risk of mold growth is at its greatest in warm, damp air. The tendency of individual spices to grow mold depends on their hygroscopic behavior. With highly hygroscopic types (vanilla, pepper), the risk of mold attack is very great. However, in the case of vanilla it is important not to confuse the precipitated vanillin crystals with mold. Mace, for example, has a tendency to go moldy and then smell bad, so considerably impairing its quality. Cloves which have become damp are worthless, becoming grey, sticky, soft and ungrindable.

It is clear from the sorption isotherm for pepper that, at the water contents of 10 - 15% indicated in Table 22, it is at equilibrium with a rel. humidity of 40 - 55%. Water vapor release may cause it to lose several percent of its weight during a relatively long voyage. Where ventilation is inadequate, pepper becomes wet, swells and has a tendency to undergo self-heating. Container dry pepper suffers only 0.5 - 1% shrinkage.

Without ventilation in standard containers, fresh pepper can become completely worthless within a few days due to self-heating. In addition to the water content, the risk of self-heating is also explained by the relatively high content of fatty oils (see Table 22). The drying process must be complete and care must be taken during packing into the container to ensure that the product is container dry. Relative humidity should be between 60 and 70%, and over a relatively long period 75% (mold growth threshold) must not be exceeded.

Odor
The content of essential oils, which may vary for the various types of spices from 0.4% (coriander, saffron) to 20% (cloves) (see Table 22) and which, together with other constituents, e.g. fatty oils, tannins and bitter principles, determines the odor and flavor and thus quality of the spices, must be retained to the greatest possible extent. The essential oils are readily volatilized and the seasoning action of the spices is consequently reduced. Volatilization of the essential oils is primarily determined by temperature. The higher is the temperature, the more the essential oils are volatilized, as may be recognized by the intense odor in the container.

Due to the readily volatilized essential oils, most spices count as odor-emitting goods and should therefore be stowed in a container separately from each other and away from foodstuffs which readily absorb foreign odors (e.g. cloves should not be stowed with coffee or tea etc.).

On the other hand, however, spices are also sensitive to foreign odors and must not there be stowed together with odor-emitting goods. The risk of odor transmission is even greater if the spices have already been ground prior to transport (e.g. chili powder), as the enlargement of surface area associated with the grinding process gives the essential oils a greater chance of volatilizing.

Transport instructions
Standard containers stuffed with spices should be stowed below deck. The extreme temperature differences on deck of up to 60°C (between day and night) may result in container sweat. Even in winter, a sharp drop in temperature may result in container sweat. Below deck, these effects are considerably reduced. The bottom, sides and top areas in a standard container should at least be lined with packing paper. A suspended nonwoven fabric provides good protection against dripping sweat.

Ventilated containers must be stowed below deck, since they have to be actively ventilated from outside when the hatch is closed. There must be no dunnage at the sides and in the top area, since it would impair ventilation action.

Turmeric, the main ingredient in curry powder, is a dusty product causing yellow color contamination and must be handled accordingly. Vanilla, for example, is at particular risk of theft due to its high value.

Insect infestation/Diseases
Spices may be infested with animal pests, especially rats, mice, beetles and their larvae (in particular drugstore beetles, hump spider beetles, Australian spider beetles and golden spider beetles), moths (dried fruit and cacao moths) and mites. Nutmegs must not be wormy. Infested goods must not be loaded into containers and equally the containers must be free of pests. If fumigation has been performed, a fumigation certificate must be available.

17.6 Semiluxury items

Characteristics and fitness for container transport
The term "semiluxury items" covers foodstuffs generally of vegetable origin, which have a stimulating, pleasant effect. They include for example coffee, cocoa, cola, coca, betel, tobacco and tea. Here, we shall look particularly at coffee and cocoa on the one hand and tobacco and tea on the other.

With low water contents, which amount to 4 - 14%, e.g. coffee 9 - 13%, cocoa 5 - 6%, tea 4 - 6% and oriental tobacco 12 - 14%, these goods are among those whose respiration processes are suspended but in which biochemical, microbial and other decomposition processes still proceed, i.e. goods displaying 3rd order biotic activity (BA 3) (see Table. 20).

Coffee, cocoa, tea and tobacco require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI). Their sorption isotherms (see Fig. 130) exhibit a continuous S-shaped profile. If they become damp, they may go moldy and undergo self-heating. On the other hand, they are subject to drying-out, associated with loss of aroma, if humidity levels are too low. Moisture and heat tend to cause postfermentation. They do not have any particular requirements as to ventilation conditions, if they are container dry.

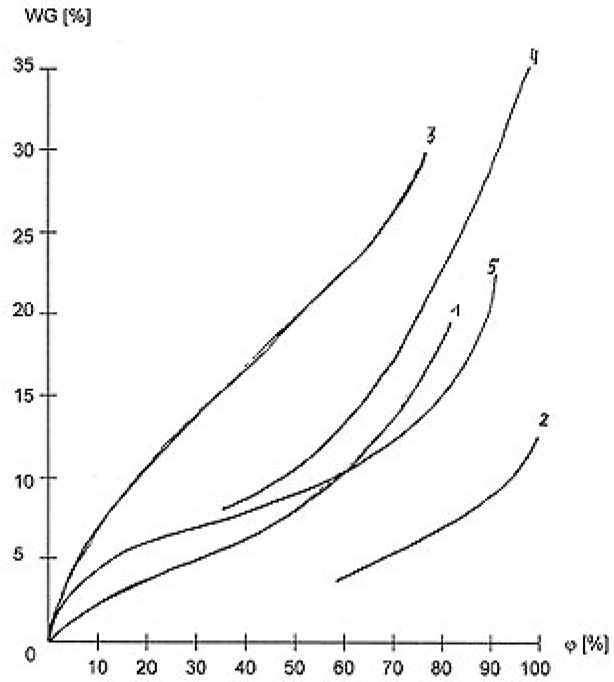


Figure 130: Sorption isotherms for semiluxury items

1 - Darjeeling tea (20°C)
2 - Cocoa beans (raw cocoa) (20°C)
3 - Tobacco leaves (30°C)
4 - Oriental tobacco (20°C)
5 - Coffee beans, green (20°C)

Due to their stringent requirements with regard to temperature and relative humidity, semiluxury items should be transported in ventilated containers (coffee containers). In addition to coffee, it has also proved possible to transport tea and oriental tobacco, in particular, in standard containers.

Below are Figures illustrating coffee (131 - 135), cocoa (136 - 138), tobacco (139 - 144, 147-148) and tea (145, 146, 149-153).

Transport instructions and damage

General
Green coffee beans and raw cocoa (cocoa beans) are seeds which have had the husk removed by fermentation and, in the case of coffee, also the silver skin. In the case of coffee, these seeds are still viable. Tea and tobacco consist of fermented, dried leaves. Unlike green coffee beans, raw cocoa and leaf tobacco, tea is exported in ready-to-use form (green and black tea). As semiluxury items (stimulants), coffee contains the alkaloid caffeine (0.8 - 2.5%), cocoa contains theobromine (1 - 2%) and caffeine (0.2%), tobacco contains nicotine (0.5 - 3%) and tea theine (2.5 - 5%). Due to its high content of fat (cocoa butter), protein and carbohydrates, cocoa also has a high nutritional value.

Processing methods
Coffee, cocoa, tobacco and tea are processed using fermentation. In the case of coffee, a distinction is drawn between dry processing and wet processing, Wet-processed coffee tends to go moldy and to suffer self-heating more quickly than dry-processed coffee. The ability to germinate is also retained despite fermentation. The loss of the ability to germinate has an unfavorable effect on the constituents and thus also on the quality of the green coffee beans (see Figs. 131-135).

Figure 131: Coffee

1 - coffee branch with flower and fruit
2 - coffee cherry
3 - cut open coffee cherry
4 - coffee bean
5 - longitudinal section

1 - pulp
2 - parchment
3 - silver skin
4 - coffee bean

Figure 132: Green coffee beans, Peruvian arabica; Photo: U. Scharnow

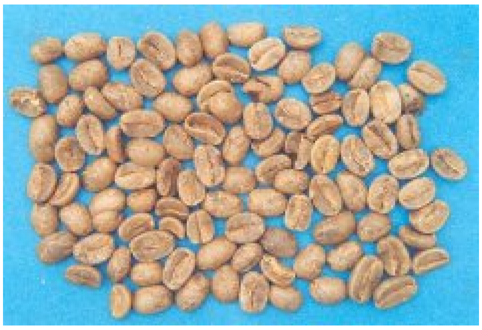


Figure 133: Green coffee beans, Ugandan natural robusta; Photo: U. Scharnow

Figure 134: Wet-damaged green coffee beans, stuck to the sacking; Photo: Goy

Figure 135: Swollen green coffee beans; Photo: Goy

Although cocoa beans lose their ability to germinate as a result of fermentation, poorly fermented cocoa beans may germinate. Over- and underfermentation may impair quality (see Figs. 136 - 138).

Figure 136: Cucumber-like cacao fruit on the trunk of the cacao tree (cauliflory);
Photo: U. Scharnow

Figure 137: Cocoa beans (raw cocoa);
Photo: U. Scharnow

Figure 138: Container with wetting damage raw cocoa, sides lined with paper dunnage;
Photo: Stradt

In the case of tobacco, a distinction is drawn between natural curing (sun curing of Oriental tobaccos, see Figs. 139 and 140, highly weather-dependent) and artificial curing (generally used for Virginia tobacco, see Fig 141). Two types of fermentation are used, natural and chamber fermentation.

Figure 139: Curing of tobacco leaves in Bulgaria;
Photo: U. Scharnow

Figure 140: Curing of tobacco leaves in Bulgaria;
Photo: U. Scharnow

The tobacco leaves, which are harvested at different times, are known as (from bottom to top = stalk position) primings/flyings, lugs, cutters, leaf, tips (see Fig. 141).

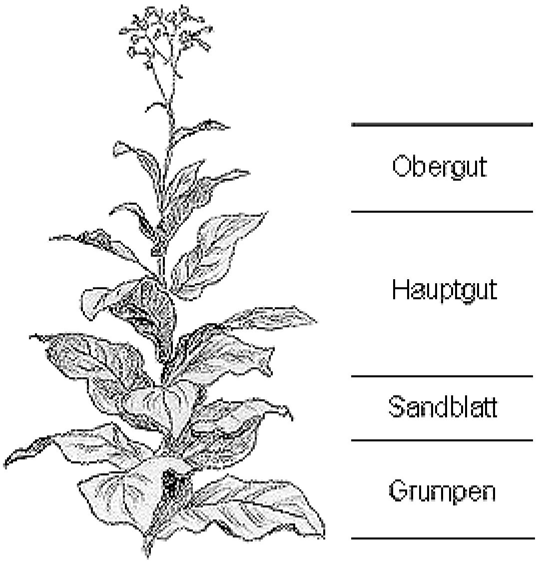


Figure 141: Tobacco plant: names for foliage [50]

Familiar types of tobacco are Oriental (see Fig. 142) and Virginia (see Fig. 143). Cigarette tobacco, e.g. American Blend, which is a mixture of Virginia, Burley and Oriental, is transported all over the world.

Figure 142: Oriental tobacco from Greece, sun-cured; Photo: U. Schieder

Figure 143: Virginia tobacco from the USA; Photo: U. Schieder

Figure 144: Burley tobacco (ribs); Photo: U. Schieder

Figure 145: Tea branch

Tea is divided into leafy and broken grades; the youngest, small top leaves (pekoe tips) provide the most valuable teas (see Fig. 146).

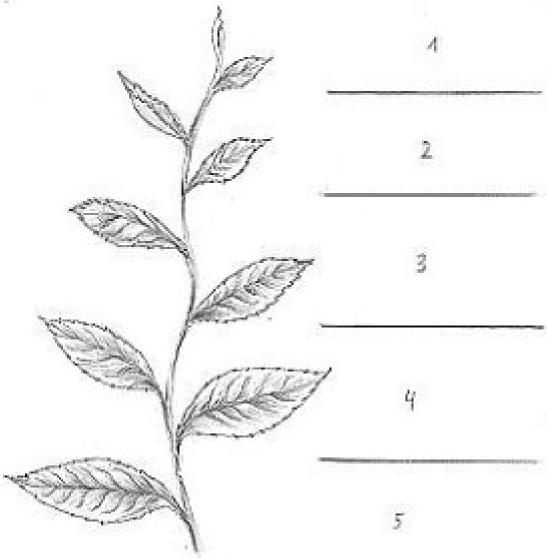


Figure 146: Tea grades as a function of leaf size -

1 - pekoe tip, thin, wiry, covering of silky hairs
2 - slightly twisted, white to golden yellow tips
3 - somewhat coarser leaf
4 - coarse leaf
5 - very coarse leaf

Tea is withered, rolled, fermented and dried.

Packaging
Coffee and cocoa are transported in new, air-permeable, natural fiber bags (sisal, jute). If plastic inner bags are used, they must be perforated. Tobacco is exported in bales, which are wrapped in natural fiber fabric (see Fig. 147) (jute, linen or blended fabric). Oriental tobacco is transported in cartons (see Fig. 148) in standard containers, having been separated into leaves and ribs (see Fig. 144). Since carton dimensions are adapted to container dimensions, full container loads (FCL) can easily be achieved in standard containers.

Figure 147: Tobacco in bales (natural fiber fabric) from Turkey;
Photo: U. Schieder

Figure 148: Tobacco in cartons, strapped with steel straps;
Photo: U. Schieder

Tea is packaged in plywood chests which are lined with aluminum foil and parchment paper, the corners being covered with sheet metal (see Figs. 150, 153). 10 - 25 packages are combined to form a palletized unit.

Figure 149: Tea gardens in Grusinia;
Photo: Ragna Scharnow

Figure 150: Tea chests from Japan;
Photo: U. Scharnow

Figure 151: Flowery pekoe leaf grade: finest Ceylon harvest F.P.
Photo: U. Scharnow

Figure 152 (top): Green tea from China;
Photo: U. Scharnow

Figure 153 (left): Plywood tea chest with aluminum foil and parchment paper, the corners being covered with sheet metal

Hygroscopicity

The semiluxury items coffee, cocoa, tobacco and tea are strongly hygroscopic. The values stated in the Table below are respectively averages and ideal temperatures.

Semiluxury item	Water content in %	Equilibrium moisture content in %	Temperature in °C
Coffee	10 (crit. 12)	50 - 65	5 - 25
Cocoa	6 - 8 (crit. 8.5)	70	15 - 25
Oriental tobacco	12 - 14	60 - 65	5 - 25
Virginia tobacco	10 - 13	50 - 65	5 - 25
Tea	4 - 6	50 - 60	5 - 25

Table 23: Water contents, equilibrium moisture content and temperature of semiluxury items [28]

The stated temperature ranges are those at which the individual semiluxury items can be stored for the longest period without quality degradation (optimum storage or transport temperature). Upward or downward deviations reduce the storage period within which no quality degradation is to be expected. The greater the deviation from the optimum storage or transport temperature, the greater the risk of quality degradation.

Their sorption isotherms (see Fig. 130) exhibit an S-shaped profile. Cocoa beans are the semiluxury item which

displays the greatest moisture sensitivity. At the time of container packing, the water content is 6 - 8%, which corresponds to an equilibrium moisture content of 75 - 85% and a temperature/dew point difference of 5 - 3°C. These are values which entail greater problems than are encountered, for example, with coffee transport, because even the lower water content limit of 6% corresponds to the mold growth threshold. Moreover, cocoa beans have an elevated fat content of 39 - 60% which, in conjunction with moisture, results in hydrolytic/enzymatic fat cleavage and thus in self-heating of the cocoa beans. The small temperature/dew point difference also shows how rapidly the dew point of the cocoa cargo is reached on cooling. A water content of 6% is thus recommended when transporting cocoa beans in containers.

Semiluxury items should be processed and dried/cured after harvesting to such an extent that they reach fitness for container transport. After processing, they must be stored in dry conditions or preferably loaded as soon as possible. Over an extended storage period in a damp, tropical climate (e.g. during the rainy season), water vapor is absorbed, which may lead to moisture damage. This may take the form of mustiness, mold, swelling or self-heating. Moreover, postfermentation may be activated (see Figs. 134, 135). In the case of tea, excessively high water contents lead to mold and mustiness. On the other hand, if the water content of tea and tobacco falls below the admissible value, they will dry out, suffer fragmentation damage, loss of aroma and leaf breakage and turn to dust. Oriental tobaccos are the most sensitive to moisture of all tobaccos. Mold (Oespora tabaci) may appear within three days, together with mustiness and decay, and may be recognized from white, grey, green and black spots on the tobacco bales.

Temperature
The temperatures stated in Table 23 are the temperatures favorable for semiluxury items. If the temperatures stated in Table 23 are exceeded markedly, with coffee the risk of rancidity and overfermentation increases. In extreme cases, the embryo may even die and rot (stinker).
With cocoa, temperatures > 30°C increasingly promote postfermentation, rancidity and self-heating. On the other hand, it must be protected from frost.

Ventilation

- Standard containers
  The ventilation holes in standard containers have no ventilation effect

  During a voyage from the tropics to temperate latitudes, a sudden drop in temperature has to be expected especially in the winter months. The temperature gradient may amount to as much as 50 - 60°C, especially during winter in the northern hemisphere.

  Due to the associated severe cooling, the temperature may reach or even fall below the dew point, resulting primarily in condensation (sweat) on the container ceiling. Dripping condensation water may cause considerable damage.

  To protect the cargo, top or lateral dunnage in the form of paper or nonwoven fabric may be laid on the cargo surface and between the cargo and the container walls. Since paper is markedly less absorbent than nonwoven fabric, nonwoven fabric is preferred for the cargo surface (see Fig. 138). Both options are only temporary measures, since their absorbency is limited. It is therefore advisable to stow the containers below deck, in order to avoid container sweat caused by the steep temperature gradient on deck. If bulk loading (coffee) is used, a liner bag with integral nonwoven fabric suspended in the standard container offers the possibility of minimizing damage.

- Ventilated containers
  Since hygroscopic semiluxury items constantly release water vapor during the voyage, with this reaching markedly more than 100 liters in a 20' container in extreme cases, this vapor must be removed by ventilation in order to reduce the risk of condensation in the event of unfavorable ambient conditions (sudden drops in temperature of the external air) in the container. Relatively high humidities bring with them the risk of mold growth and self-heating. To optimize ventilation in a passively ventilated container, the container must be stowed below deck (under the hatch). As soon as the external temperature falls below loading temperature and the relative humidity is no longer above the loading humidity, it is advisable to assist passive ventilation. The "chimney" effect must be achieved by vigorous ventilation of the hold, with the air being blown in from beneath and rising upwards through the container cargo, so continuously removing warm, moist air.

  Dunnage is only laid on the floor; at the sides and in the top area the ventilation effect would be impaired. It is also important to unpack (strip) the containers quickly on arrival at the port of destination. Especially at cold times of year, when the containers are removed from the relatively protected environment of the ship's hold, the core temperature of coffee may still be 18 - 20°C. If they are then exposed to the sometimes substantially lower external temperature, the humidity in the containers rises rapidly, so causing condensation to form.

  Ventilated containers are used to transport tobacco from regions with critical climatic conditions (e.g. Indonesia, Dominican Republic).

Odor
All semiluxury items are capable of absorbing foreign odors, if the containers are not clean and odor-free prior to packing. Any residues from previous cargoes, especially odor- and flavor-tainting cargoes, must be removed. It may be necessary to wash the container. If the previous cargo was extremely strong-smelling, e.g. salted hides, the container must be rejected. Unsealed container floors cannot be lastingly cleaned of these odors - only replacement of the container floor is sufficient.

Contamination
All semiluxury items are extremely sensitive to contamination and care should therefore be taken, when packing and unpacking a container, to ensure that contamination from ground conveyors, e.g. hydraulic oil, grease etc., is not transferred to the sensitive cargo. Dunnage, where used, must also be dry, odor-free and clean.

After washing, care must be taken to ensure that the container floor has dried out. The moisture content of the container floor should amount to no more than 12% at an equilibrium moisture content of 70%.

Mechanical influences
Before ground conveyors with squeeze clamps are used to pack and unpack the containers, checks must be carried out to find out what clamping pressure the packaging (cases, bales or cartons) is designed to withstand. If coffee or cocoa is to be loaded in bags, only bag hooks must be used; under no circumstances should a longshoreman's hook be used.

Toxicity/Hazards to health
Postfermentation causes CO_2 production. In unfavorable cases, high carbon dioxide contents may arise. Contents of 8 - 10 vol.% are lethal within just five to ten minutes! Since CO_2 is heavier than air, it "flows" out like water when the container is opened. It is therefore highly unlikely that a situation which was hazardous to health would arise in the container. If a container has been fumigated to combat pests, the container must be marked accordingly. Prior to packing, the container must be ventilated in accordance with the instructions relating to the pesticide.

Insect infestation
Some pests specialize in infesting the corresponding cargo type, e.g. the coffee beetle, the cacao moth and the tobacco beetle (cigarette beetle). The tobacco beetle is in particular brought on board in the tropics and subtropics. The cocoons are attached to the interior of the packages. The larvae chew round holes in the tobacco leaves. For the purpose of identifying any pests, traps are set in the container which are checked on unpacking. Infested cargoes must be fumigated, but their quality may well be degraded as a result. A fumigation certificate must be presented in this case.

17.7 Crystalline goods

Characteristics and fitness for container transport
Sugar and salt are classed as hygroscopic crystalline goods. Hygroscopic crystalline goods differ from the preceding hygroscopic goods in that they have a substantially lower water content
(WC > 0 - < 1.5%), and thus belong to water content class 1 (WCC 1). Moreover, due to their crystalline structure, their adsorption behavior is governed by different rules, which means different container transport methods are used.

Crystalline goods belong to the class of goods in which respiration processes are suspended, but in which biochemical, microbial and other decomposition processes still proceed; they exhibit 3rd order biotic activity (BA 3).

Crystalline goods have particular storage climate conditions with regard to temperature, humidity/moisture and ventilation (SC VI) in order to counter the risk of deliquescence or agglomeration (sticking together).

Crystalline goods are transported in bulk containers and standard containers.

Sugar (sucrose) occurs commonly in the plant kingdom. However, only sugar cane and sugar beet are cultivated for the large-scale industrial production of sugar. Chemically speaking, both cane and beet sugar are sucrose, $C_{12}H_{22}O_{11}$. While sugar cane is cultivated in the tropics and subtropics, sugar beet is cultivated in temperate latitudes. Given the different regions in which it is produced, sugar is transported:

- from the tropics to temperate latitudes for cane sugar
- from temperate latitudes to the tropics for beet sugar

The direction of travel between these two climatic zones is of relevance to container transport, but the nature of the sugar (whether cane or beet) is immaterial.

Sugar is classified, among other things, by its purity, which determines different transport properties.

Raw sugar is a "moist", coarsely crystalline mass with a sucrose content of 95-97%. The solid cores of the raw sugar crystals are still covered with a layer of syrup. These accompanying substances make raw sugar moist and tacky and give it its typical yellow-brownish color and malty, burnt flavor. The water content of raw sugar is 0.5 - 1% (see Fig. 154).

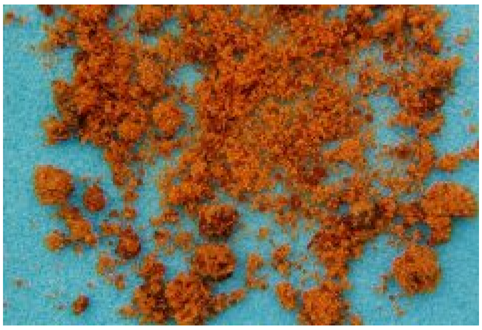


Figure 154: Sucanat (whole cane sugar); Photo: U. Scharnow

White sugar is regular consumer sugar. It is obtained from raw sugar by washing and centrifuging (affination). Its sucrose content is 99.9%.

Refined sugar is chemically ultrapure sucrose which has been obtained from white sugar by dissolution and recrystallization. It also has a sucrose content of 99.9%.

Powdered sugar is produced by grinding white or refined sugar crystals to a fine powder and sieving the powder. The max. grain size is 0.05 mm.

Salt (cooking salt), chemically sodium chloride (NaCl): mainly mined as rock salt or obtained from sea salt pans (see Fig. 155). Depending on how it is produced, salt is classified as rock salt or boiled salt. Rock salt, which is mined and finely ground, is primarily used in the food industry. Boiled salt is obtained from brine and has a higher content of magnesium chloride and calcium chloride than rock salt, as a result of which it is more highly hygroscopic than rock salt, with the finely divided grades being more highly hygroscopic than the coarser grades. Boiled salt also agglomerates more readily than rock salt.

Figure 155: Refined rock salt; Photo: U. Scharnow

Hygroscopicity

Initially, crystalline goods hardly respond at all to the water vapor content of the ambient air, such that their water content is close to 0% (flat adsorption isotherm). Only once the flow moisture point is reached, which for example for sugar is > 80%, does the sugar absorb water vapor so quickly and in such large quantities that it deliquesces (abrupt rise in adsorption isotherm) and loses its flowability (see Fig. 156). When moistened sugar dries out, it releases the absorbed water vapor to its surroundings and hardens and cakes.

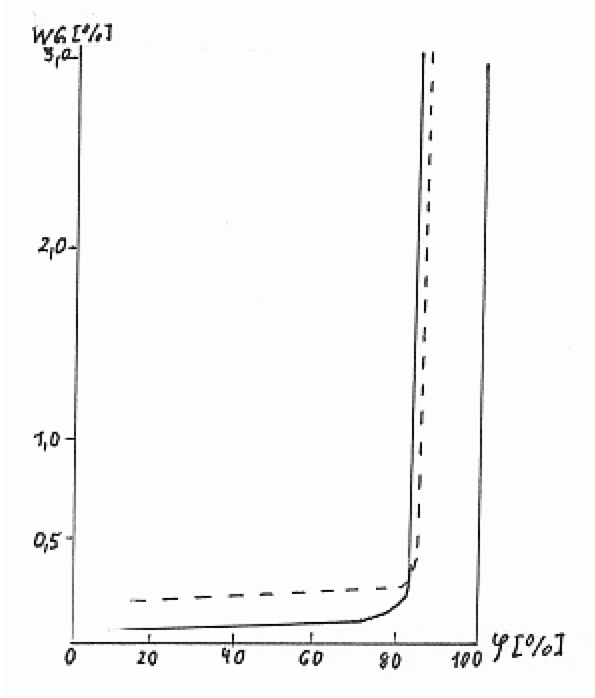


Figure 156: Sorption isotherms for white sugar

— 20°C
--- 10°C

The sorption isotherm for cooking salt (see Fig. 157) shows that it absorbs virtually no water vapor from its surroundings at relative humidities of up to 74%. Once the water content has risen from 0.05% to 0.5%, so reaching the flow moisture point, salt begins to absorb water vapor so readily that it passes into solution at a relative humidity of 75%.

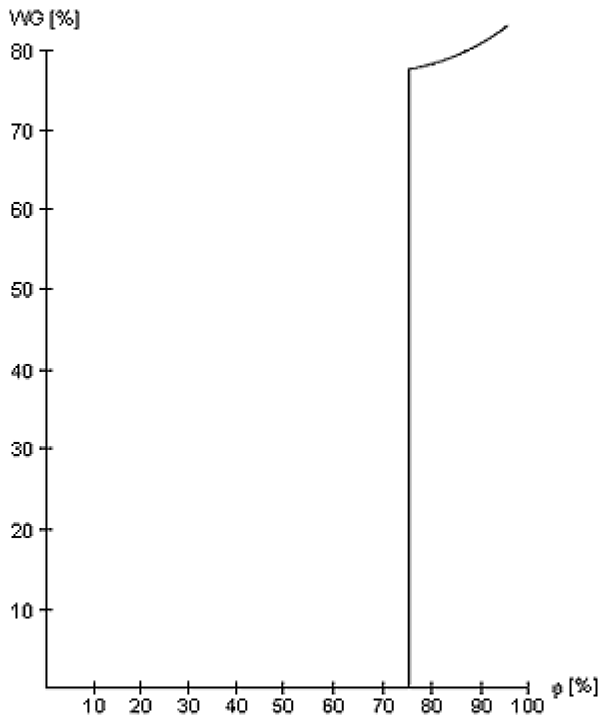
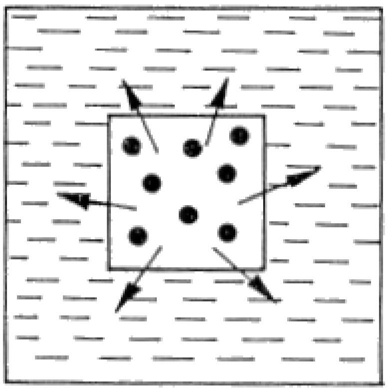


Figure 157: Sorption isotherm for cooking salt
(sodium chloride, 20°C)

Behavior of sugar in a container in the event of temperature changes

- Transport of raw sugar from the tropics to temperate latitudes (see Fig. 158).

  This applies, for example, to the transport of sugar from Central America to Europe. Especially during winter in the northern hemisphere, cargoes of sugar on this route are at risk due to the temperature differences. Air and water temperatures begin to drop from around 20°N and continue to do so until arrival in Europe. Over this voyage of approx. 4000 sm, air temperature may be expected to fall, for example, from 28°C to 2°C, with water temperature dropping from approx. 20°C to 5°C. A drop in air temperature of around 26°C and in water temperature of around 23°C create the conditions for caking of the sugar in the container. Investigations have shown that losses due to caking are at their highest in the cold season. However, losses due to caking are particularly prevalent when relative humidity falls below 50%.



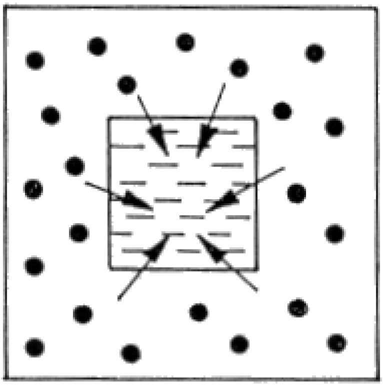


Figure 158:
Travel from hot to cold regions: The cargo block cools down from the outside, resulting in water vapor transport from the warm core to the outside; caking in the interior due to water vapor release from the hot cargo [27]

Figure 159:
Travel from cold to hot regions: the cargo block is heated from the outside, resulting in water vapor transport from the outside to the cold core; caking on the outside, wetness on the inside [27]

-

- Transport of white sugar from temperate latitudes to the tropics (see Fig. 159).

  On relatively long voyages, the inner bags of the stack remain cold for longer; due to the different sorption behavior, water vapor is conveyed from the warmer outer sugar to the colder sugar inside the stack. This results in water stains on the sugar bags and, on the basis of the above observations, syrup formation may be expected. Subsequently, once the internal sacks have also warmed up, severe caking starts to occur. Crystalline goods are now predominantly transported in double-layered packaging consisting of a outer, woven bag and an inner, plastic film bag. This avoids the risk of water vapor adsorption or caking when the white sugar redries (see Figs. 160, 161).

Figure 160: Double-layered bags containing white sugar: outside, natural fiber fabric; inside, plastic;
Photo: U. Scharnow

-

Figure 161: Palletized double-layered plastic bags containing white sugar;
Photo: U. Scharnow

Contamination
Since crystalline goods are virtually exclusively transported in combined fabric/film bags, they are not very sensitive to (dust) contamination. Deposits on the bags may result in losses. Containers must be sufficiently clean for food cargoes. Crystalline goods, such as sugar and salt, are basically clean foodstuffs which are packaged hermetically. If packaging is damaged during loading, salt in particular may have a strong corrosion-promoting effect on other goods.

Fire hazard
Smoking must be strictly prohibited during container packing and unpacking. Discarded cigarette ends can cause sugar fires. Cigarette ash acts as a catalyst in sugar combustion. Sugar fires are greatly feared because they are difficult to extinguish, requiring the use of carbon dioxide or other chemical extinguishing agents.

18 Liquid goods

18.1 Oils & fats

Characteristics and fitness for container transport
"Oils" is a collective term for more or less viscous, generally organic-chemical liquids. Depending on their chemical composition, a distinction may be drawn between fatty, essential, mineral and silicone oils. Fatty oils include liquid, semisolid and solid products of vegetable and animal origin, also known as sweet oils. Sweet oils are obtained by cold pressing (at 32 - 40°C) or by hot pressing (at 70 - 90°C). They comprise mixtures of glycerides (esters of glycerol) with partially unsaturated fatty acids, e.g. oleic, linoleic and linolenic acid, and partially saturated fatty acids, e.g. butyric acid, palmitic acid.

Sweet oils do not contain any water, and belong in water content class 0 (WCC 0). They also belong to the class of goods in which respiration processes are suspended, but in which biochemical, microbial and other decomposition processes still proceed. They display 3rd order biotic activity (BA 3).

Sweet oils are transported in tank containers, if they do not require any particular storage climate conditions (SC 0), or in heatable tank containers, if they can only be kept in the liquid state by heating, i.e. require particular temperature conditions (SC II). When selecting a tank container or heatable tank container, it is essential to take account of the temperatures to be expected due to the route, season etc..

As a result of their particular properties, vegetable and animal fatty oils and fats undergo various changes, which have to be taken into account during transport in order to avoid quality degradation. The following transport properties must be taken into account when using container transport: density, thermal dilatation, phase changes, iodine value, acid value, rancidity, isomerization, polymerization, contamination and transport temperatures.

Transport instructions and damage

Density
Fatty oils and fats have a density of approximately 0.9 g/cm^3 (see Table 24) and are insoluble in water. Oil density is determined using an areometer, while fat density is determined using a pycnometer.

1 Babassu fat	8 Coconut oil	15 Palm oil	22 Mustard oil, white
2 Cottonseed oil	9 Camelina oil	16 Rapeseed oil, colza oil	23 Sesame oil
3 Cod-liver oil	10 Linseed oil	17 Castor oil	24 Soy oil
4 Peanut oil	11 Menhaden oil	18 Seal oil	25 Sunflower oil
5 Hemp oil	12 Olive kernel oil	19 Safflower oil	26 Suet, beef
6 Herring oil	13 Olive oil	20 Lard	27 Teaseed oil
7 Kapok seed oil	14 Palm kernel oil	21 Mustard oil, black	28 Tung oil, Chinese
			29 Whale oil

No. (commercial name) 1 to 29 in Table 24 (below)

No.	Acid value max. in %	Density at 15°C in g/cm³	γ per 1 K	Solid-ification range in °C	Loading temp. in °C	Travel temp. in °C	Pumping temp. in °C	Iodine value	Storage climate conditions	Contai-ner type
1	1.0 - 2.0	0.925	0.000700	23 - 22	33	24	46 - 55	13 - 17	SC II	Heat. tank cont
2	0.81 - 1.20	0.917 - 0.923	0.000720	11 - 1	17	15 - 20	32 - 35	103 - 111	SC II	Heat. tank cont
3	2.0	0.924 - 0.931	0.000700	0 - -10	10 - 15	5 (3 - 5)	< 20	143 - 173	SC 0	tank cont.
4	3.5 - 4.0	0.911 - 0.925	0.000675	3 - -2	10	12 (4 - 15)	12	86 - 98	SC 0	tank cont.
5	2.7	0.927 - 0.932	0.000720	-15 - -27	23	15 (12 - 23)	15	150 - 167	SC 0	tank cont.
6	4.0	0.922 - 0.930	0.000700	10 - 5	20 - 25	10 (8 - 10)	20	108 - 155	SC II	Heat. tank cont
7	2.3	0.920 - 0.923	0.000720	13 - -8	24	15.6	24 - 29	85 - 100	SC II	Heat. tank cont.
8	1.0 - 2.0	0.919 - 0.937	0.000720	25 - 14	35	24 - 32	40 - > 55	7 - 10	SC II	Heat. tank cont.
9	1.3	0.919 - 0.926	0.000720	-15 - -18	23	15 (12 - 23)	23	133 - 153	SC 0	tank cont.
10	1.2 - 1.9	0.927 - 0.935	0.000660	-18 - -27	23	20 (15 - 26)	23	169 - 192	SC 0	tank cont.
11		0.925 - 0.930	0.000700	18 - 15		35 (32 - 38)	43 - 46	189 - 198	SC II	Heat. tank cont.
12	2.0	0.918 - 0.920	0.000720	0 - -9		15(12 - 25)		82 - 88	SC 0	tank cont.
13	2.0	0.914 - 0.919	0.000720	0 - -9	20	15	20	75 - 88	SC 0	tank cont.
14	3.0 - 7.5	0.925 - 0.935	0.000727	24 - 19	35	>24	50 - 55	12 - 18	SC II	Heat. tank cont.
15	0.1 - 1.0	0.925 - 0.947	0.000727	41 - 31	40	30 (25 - 35)	49 - 50	43 - 48	SC II	Heat. tank cont.
16	0.6 - 2.0	0.908 - 0.917	0.000675	0 - -15		15 (12 - 24)	15	94 - 106	SC 0	tank cont.
17	1.0	0.950 - 0.968	0.000700	-10 - -18		15 (12 - 25)	30 - 35	81 - 100	SC 0	tank cont.
18	4.0	0.925 - 0.934	0.000700	3 - -3	25	10 (8 - 10)	25	144 - 193	SC 0	tank cont.
19		0.916 - 0.925	0.000746	-13 - -20		15 (12 - 19)		130 - 150	SC 0	tank cont.
20	0.8 - 1.2	0.914 - 0.922	0.000700	32 - 22		38	50	46 - 66	SC II	Heat. tank cont.
21	6.1	0.914 - 0.923	0.000700	-11 - -17		15 (12 - 20)	15	96 - 107	SC 0	tank cont.
22	6.1	0.907 - 0.921	0.000700	-8 - -16		15 (12 - 18)	15	92 - 108	SC 0	tank cont.
23	1.0 - 1.4	0.919 - 0.934	0.000700	-3 - -6		15(4 - 25)	20	103 - 112	SC 0	tank cont.
24	0.9 - 1.3	0.922 - 0.927	0.000746	-8 - -18	24	15 (12 - 25)	27	128 - 135	SC 0	tank cont.
25	0.9 - 1.1	0.918 - 0.927	0.000746	-16 - -18		15 (5 - 26)	15	118 - 144	SC 0	tank cont.
26	2.0	0.936 - 0.952	0.000700	38 - 30	50 - 70	43 - 46	54 - 57	32 - 47	SC II	Heat. tank cont.
27	1.0	0.913	0.000700	0 - -10	23	15 (12 - 25)	23	86 - 90	SC 0	tank cont.

28	4.0	0.936 - 0.945	0.000700	3 - 2	10	15 (>5 - 25)		142 - 172	SC 0	tank cont.
29	4.0	0.940 - 0.950	0.000685	-8 - -14	20 - 25	20 (10 - 25)	not < 20	102 - 170	SC 0	tank cont.

Table 24: Sweet oils

Thermal dilatation
Density depends on temperature, so meaning that the volume occupied by the oil varies as a function of the temperature of the oil. Although it is necessary to fill the tank container as full as possible, to limit any oxidative processes in the oil, the thermal dilatation of the oils does have to be taken into consideration on loading. The change in volume resulting from the change in temperature follows the equation:

$\Delta V = Va \times \gamma \times \Delta t$

in which
ΔV change in volume
Va volume at initial temperature a
γ coefficient of cubic (thermal) expansion
Δt temperature difference in °C

For general calculations, 0.007/°C is an acceptable approximate value. As a rule of thumb, oils may be expected to increase in volume by 1% of their total volume for each 14°C temperature increase. In particular in the case of oils requiring heating, the ullage space must be calculated accordingly.

Phase changes
Solidification and melting temperatures are of considerable significance in the transport of fatty oils and fats. They depend on which fatty acids predominate in the oil or fat.

Fats of a solid consistency primarily contain saturated long-chain fatty acids, e.g. palmitic acid and stearic acid. Some have high melting temperatures, e.g. beef suet. Semisolid and liquid fats consist primarily of the glycerides of unsaturated fatty acids, e.g. oleic acid, linoleic acid and linolenic acid. The predominance of unsaturated fatty acids means that the characteristic melting temperatures of fatty oils are lower than those of fats. The fat of land animals is generally solid, while that of marine animals is liquid.

Where fatty oils are transported in tank containers, it is essential that they remain in the liquid state during loading, the voyage and pumping; chill haze (separation), which begins if cooling causes the temperature of the oil to approach solidification point, is therefore important.

As cooling progresses, the oils become ointment-like and finally solid. This separation and the associated change in consistency from liquid to solid occurs more readily upon cooling, the higher is the oil's solidification point.

Due to the gradual transition from one state to the other which is usual in oils, solidification range would be a better term to use. This phase change is a reversible process, i.e. the oil becomes liquid and clear again when heated (see below under transport temperatures).

Iodine value
Of considerable significance with regard to tank cleaning is the iodine value. This indicates how many grams of iodine are bound by a 100 g sample and is a measure of the degree of unsaturated hydrocarbons in oils and fats. It is thus a measure of how strong a tendency the oil has to oxidation and thus to drying. Drying of the oils is caused by the presence of polyunsaturated glycerides and results from the fact that, in the presence of atmospheric oxygen, these combine in a process resembling polymerization to form macromolecular compounds, such as, in the case of linseed oil, linoxyn, a viscous, solid mass. The capacity of fatty oils to absorb atmospheric oxygen is a significant factor in the transport of fatty oils, in particular with regard to cleaning the tank container. Thus, on the basis of drying capacity, oils are divided into nondrying, semidrying and drying oils.

- Nondrying oils have iodine values below 100, i.e. contact with atmospheric oxygen does not lead to any appreciable drying of the oils, e.g. peanut oil, olive oil, palm oil. The tank containers are easy to clean.
- Semidrying oils have iodine values of between 100 and 130. These oils dry within acceptable limits, e.g. cottonseed oil, sesame oil.
- Drying oils have iodine values of between 130 and 190, i.e. they dry rapidly on contact with atmospheric oxygen. Considerable cargo residues are left on tank container walls by rapid drying-on of the oils and these have to be scraped off, e.g. linseed oil, tung oil, camelina oil. This causes considerable weight losses.

Acid value
The acid value specifies how many mg of potassium hydroxide (KOH) are required to saturate the free organic fatty acids contained in 1 kg fat. Low acid values (around 1%) are not a problem. In the case of tung oil, a maximum of 4% free fatty acids is acceptable. Higher acid values degrade the quality of the oil (souring). The free fatty acid content may increase as a result of high transport temperatures. High fatty acid contents lead to souring of the oils. The free fatty acids are also oil-soluble and may cause discoloration of the oil. For this reason, for certain oils it is favorable to coat the tank walls, e.g. with plastic coatings.

Rancidity
Oils and fats spoil by becoming rancid, which entails changes to odor and taste which can make edible oils and fats inedible, e.g. cottonseed oil has a tendency to turn rapidly rancid. Rancidity is caused by autoxidative processes, which are promoted by light, atmospheric oxygen and humidity/moisture. Thus, the tanks containers must be filled as full as possible, taking into consideration the coefficient of thermal expansion, so that little ullage space is left above the oil and the cargo can move only slightly in rough seas or as a result of shaking during road or rail transport. Tank containers must be closed immediately. Tung and linseed oil are at particular risk.

Isomerization and polymerization
Decomposition (isomerization) is frequently the cause of catalysis during extended voyages and causes the sweet oil cargo to become lard-like. The risk of isomerization is especially pronounced in the case of tung oil, which is highly sensitive. Polymerization is caused in particular by the influence of heat, if, for example, the oil has been overheated. The consequence is thickening or gelling of the oil, which is also the case with oxidation.

Contamination
Oils are sensitive to mixing/contamination, e.g. kapok seed oil, which is the most sensitive of the vegetable oils. Even slight mixing with other goods can cause it to suffer spoilage. The same applies to olive oil, which is a high quality product.

Castor oil must not be contaminated by water; such contamination would make it smell like dirty, stagnant water. Oil of turpentine is sensitive to water and rust, which may cause discoloration. Tung oil becomes cloudy when mixed with water.

Linseed oil residues, which have dried on the tank walls and have not been thoroughly removed may affect the odor of subsequent, odor-sensitive oils. For this reason, before the cargo is accepted, the tank containers have to be thoroughly cleaned and dried. Old cargo residues must be removed. Fitness for loading should be certified by sworn inspectors or by a specialized cleaning company.

Transport temperatures
Some fatty oils do not need to be heated during the voyage because their solidification temperatures are low, e.g. peanut oil, olive oil, castor oil, rapeseed oil, safflower oil, sunflower oil and teaseed oil. Other fatty oils with high solidification temperatures have specific loading, travel and pumping temperatures. Table 24 lists some examples. To make the heated oil pumpable at its destination, it has to be brought to the necessary pumping temperature by heating the tank. This is only possible, however, if the oils are kept liquid during the voyage (above a minimum temperature). The prescribed loading, travel and pumping temperatures must therefore be precisely complied with, since any change in consistency which occurs during transport may prove irreversible. If the oil solidifies in the tanks, it cannot be liquefied again even by forced heating. In the vicinity of the heating coils, the oil melts, scorches and discolors. Heating does not progress, since the cargo is solid and cannot circulate. Heat conduction is slight, on the other hand, and is insufficient to liquefy the oil.

Problems also arise with these oils during pumping in cold weather, as the oil cools too rapidly in the long lines and solid deposits form on the outer walls, which cannot be pumped out. On the other hand, however, the oil must not become too hot, since excessive heat can cause chemical changes and impair or alter its quality. In general, fats may be heated up to 10% above their melting point without suffering losses in quality. It is important to start increasing the temperature to the necessary pumping temperature in good time. The temperature is increased evenly and initially only slowly, by no more than 3°C per day. The more sensitive and viscous the oil, the more carefully must it be heated. Later, when the oil has become thinner and circulation is accordingly ensured, it may be heated by 5°C per day.

18.2 Beverages

Characteristics and fitness for container transport

This section will look at beverages which are primarily transported as liquids in containers of glass (bottles), metal (cans, jerricans, barrels), plastic (jerricans, bottles) or wood (barrels).

A distinction is made between alcoholic beverages and non-alcoholic soft drinks. Alcoholic beverages contain ethyl alcohol, generally at a dilution of less than 50%. They include wines, beers, spirits and wine-containing/wine-like beverages. Non-alcoholic soft drinks include, among other things, fruit juices, table water, mineral water and lemonade.

Beverages are goods displaying 4th order biotic activity (BA 4), i.e. they are goods in which biochemical and microbial processes have stopped and which are isolated from the external environment, e.g. sterilized and pasteurized goods in hermetically sealed packaging (liquids in bottles, jerricans, cans, barrels).

Owing to this packaging, they are assigned to water content class 0 (WCC 0).

Beverages require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI), since they suffer in particular from temperature-determined physical changes, such as ice expansion rupture or heat expansion rupture of the containers due to thermal expansion (dilatation). Excessive humidity leads to damage, especially to labels. If the product, packaging and pallets are container dry, they do not need to be ventilated, and can be transported in standard containers.

Transport instructions and damage

Ice expansion rupture
From a chemical standpoint, beverages are aqueous solutions or water-containing mixtures of substances, with significant factors for their storage being the physical properties of the water, in particular its temperature-determined volume changes and expansion (dilatation) on freezing.

The anomaly of water is that, after reaching maximum density at 4°C, it continues to expand when cooled further until freezing point is reached at 0°C. The decisive factor, however, is dilatation upon transition from the liquid to the solid phase. Its volume increases by approximately 9%. This leads to elevated pressures in the contents, resulting in bursting of the container. This phenomenon is known as ice expansion rupture.

In the case of non-alcoholic soft drinks, the freezing point is lower than that of pure water, depending on the concentration of these dissolved substances in the water. An increased concentration of a solution is associated not only with a reduction in the freezing point but also a smaller increase in volume on freezing, since dilatation of the water is countered by contraction (reduction in volume) of the accompanying substances (sugar, fruit concentrate, acidulating agents etc.) (see Table. 22).

	Concentration in %	Freezing point in °C	Increase in volume in %
1	10	- 0.54	8.7
2	20	- 1.50	8.2
3	30	- 2.70	6.2
4	40	-4.50	5.2
5	50	-7.30	3.9
6	60	-12.00	0.0

Table 25: Freezing point reduction and change in volume on freezing of sucrose solutions;
Kröber [19]

With increasing cooling below freezing point, ice continually precipitates out, accompanied by segregation processes, and an ice layer a few centimeters thick is sufficient to cause ice expansion rupture of conventional glass bottle packaging, without its contents having to be completely frozen. Water-containing goods whose freezing point is just below 0°C are at particular risk of ice expansion rupture (see Table 26). With most non-alcoholic soft drinks, freezing point is between -0.3 and
-1.0°C.

	Cargo type	Freezing point in °C
1	Carbonated water	- 0.30
2	Fizzy lemonade	- 0.49
3	Fizzy orange	- 1.13
4	Tomato juice	- 1.44
5	Apple juice	- 1.69
6	Mango juice	- 1.69
7	Unfermented rhubarb juice	- 1.87
8	Malt beer, ordinary	- 1.92
9	Vollbier, pale	- 2.03
10	Unfermented sour cherry juice	- 2.15
11	Unfermented redcurrant juice	- 2.36
12	German Pilsner	- 2.42
13	Bock beer, pale	- 3.07

Table 26: Freezing points of certain beverages;
Kröber [19]

Ice expansion rupture is observed particularly frequently and severely with carbon dioxide-containing beverages contained in bottles (mineral water, fizzy drinks etc). The internal pressure arising due to the increase in volume on freezing of the water is increased still further in this beverages as a result of release of the dissolved carbon dioxide.

In contrast, ice expansion rupture is seldom observed in alcoholic beverages, especially wines and spirits, due to their lower freezing points. In addition, when wines and spirits freeze, dilatation of the water is accompanied by contraction (reduction in volume) of the alcohol, which at 35 vol.%, is so considerable that the overall volume does not expand on freezing of the water. In vollbiers, the increase in volume generally results in liquid escaping through the bottle closures.

Heat expansion rupture
In the case of liquids in glass containers, high temperatures and a high coefficient of thermal expansion may cause the containers to burst, given the considerable pressure then exerted by the contents. The risk of heat expansion rupture increases, the greater the coefficient of thermal expansion. For example, at 18°C the coefficient of cubic (thermal) expansion is 0.00018/°C for water, but 0.00110/°C for ethyl alcohol. As a consequence, in the case of ethyl alcohol the risk of heat expansion rupture is six times that of water. Alcoholic beverages are thus more at risk from heat expansion rupture than non-alcoholic beverages.

Because of the risk of ice expansion rupture, transport temperatures of less than 2°C are inadvisable for beverages, while the risk of heat expansion rupture means that temperatures of > 20°C should be avoided.

Tank containers should be loaded in such a way that sufficient ullage space is left for heat-induced expansion. Some liquids are subject to filling regulations. The shipper must state that these have been complied with.

18.3 Preserved foods

Characteristics and fitness for container transport
Foodstuffs, such as fruit, vegetables, meat, fish, soups and ready meals, which are preserved by sterilization in cans of tin or black plate, glass or composite films, are known as preserved foods. Sterilization at temperatures of 115 - 120°C kills most microorganisms, even heat-resistant spores. Air-tight closure prevents the sterilized contents from falling prey to microorganisms again. After sterilization, preserved foods are cooled and labeled. Cartons containing preserved foods are generally packed into containers on pallets.

Semi-preserved foods are those which have been preserved without sterilization and using acids or chemical preservatives, e.g. caviar, fish marinades etc..

Preserved foods are goods displaying 4th order biotic activity (BA 4), i.e. they are goods in which biochemical and microbial processes have stopped and which are isolated from the external environment, as are sterilized and pasteurized goods in hermetically sealed packaging.

Owing to this packaging, they are assigned to water content class 0 (WCC 0) like beverages.

Preserved foods require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI). They suffer in particular from temperature-determined physical changes (expansion/dilatation), which lead to heat- and cold-induced blowing. Excessive humidity leads to corrosion damage.

If the product, packaging, pallets and container floor are container dry, they can be transported in standard containers. Depending on the season and the route and duration of the voyage, refrigerated containers may also be necessary.

Transport instructions and damage
Standard containers containing preserved foods require cool slots. At relative humidities of > 70%, wetting may result in corrosion and in labels falling off. If freezing point is reached, ice expansion rupture must be expected, while temperatures > 20°C should be avoided due to the risk of heat expansion rupture. Heat-induced blowing is most frequently observed in the area of the container ceiling.

When packing the container, the packaging should be checked for intactness (risk of theft). Cartons of wet strength paperboard are preferred. The cartons should be secured with tear-resistant adhesive strips. An effective method of protecting them from moisture is to form cargo units wrapped in shrink films.

- Blowing
  The most frequent types of damage suffered by cans are swelling, known as "blowing", and corrosion. After sterilization, gas formation may cause can walls to deform and the tops and bottoms to bulge. So much gas may form that the seams may ultimately tear open and the cans burst (see Fig. 162). This phenomenon is known as blowing. The contents of blown containers are inedible or hazardous to health.

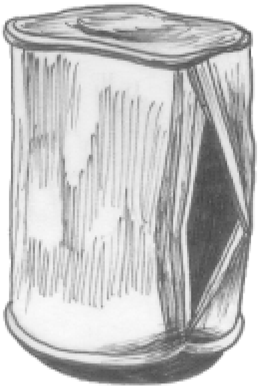


Figure 162: Blown can: side seam torn open

- **Corroded cans**
  The water content of the packaging has a considerable influence on the susceptibility of preserved food cans to corrosion. If the water content of the paperboard cartons is > 8% and that of the wooden boxes is > 12%, incidents of loss arise time and again because the cans corrode and the labels fall off. Mold and mildew formation often occur because excessively green lumber with water contents of 18 to ≤30% has been used to make the boxes.

Figure 163: Bottom of a can with pitting corrosion;
Photo: U. Scharnow

Damage due to mechanical influences
Cartons which have inadequate strength are frequently damaged when stowed and secured inadequately in the container, so resulting in denting and squashing of the cans. If the contents of the cans leaks out, the cartons become soft and the carton stacks may collapse. Jars and large cans should be packed in compartmentalized cartons (see Figs. 164, 165).

Figures 164 and 165: Dented cans
Photos: U. Scharnow

19 Industrial raw materials, semi-manufactured articles & industrial goods

19.1 Lumber & bark

Characteristics and fitness for container transport
Wood mainly consists of elongate, firmly intertwined, microscopically small cells. These cells consist of a cell wall and a cell lumen, as a result of which wood is a pore-filled material primarily consisting of cellulose, hemicellulose, lignin and water.

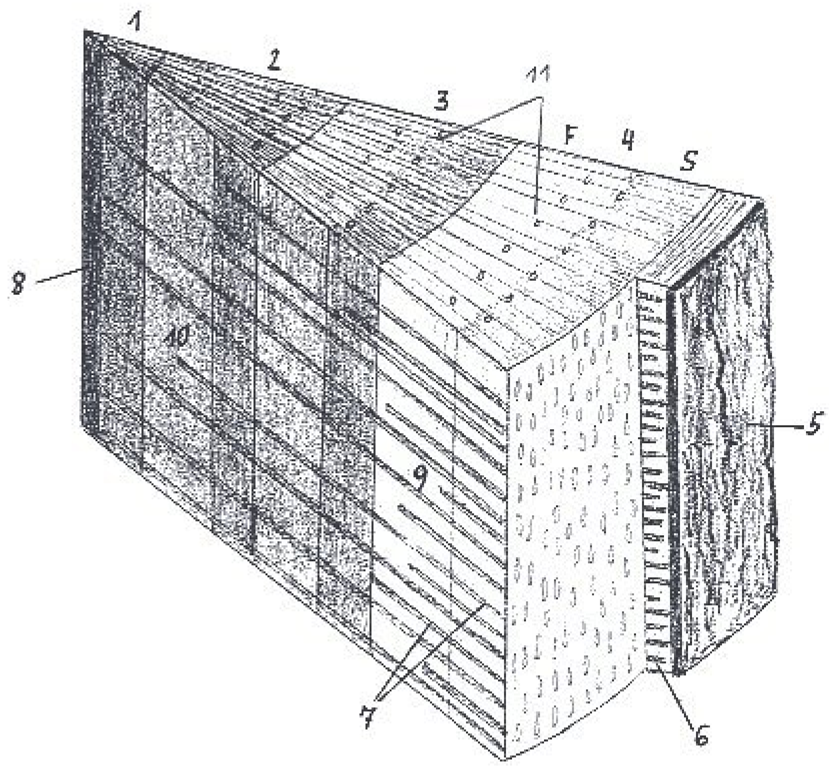


Figure 166: Segment from a four year old pine;
Schmeil [50]

1 - 4 - annual rings, F = earlywood, S = latewood
5 - bark
6 - phloem
7 - medullary rays
8 - medulla
9 - sapwood
10 - heartwood
11 - resin ducts

Figure 166 shows the macroscopic structure. In addition to the bark and phloem layers, the soft sapwood layers and the hard heartwood layers can also be distinguished. The soft, light-colored sapwood consists of living cells and

transports water and nutrients, processes which occur in the outermost annual rings. The hard heartwood consists of dead cells and is often of a dark color due to the deposition of heartwood substances, such as tannins and colorants, resins and other lumber constituents, as well as storage materials. In comparison to sapwood, heartwood has a lower water content, is heavier, harder and more durable.

- Trees with a large proportion of heartwood are known as heartwood trees, for example mahogany, cedar and oak (see Fig. 167).
- Sapwood trees which exhibit no difference in color and water content between the inner and outer wood are, for example, birch, willow and lime.
- Dressed lumber is lumber from which the sapwood has been removed. Sapwood is highly susceptible to insect attack, while heartwood is less so.

Figure 167: Makore: tropical roundwood from West Africa with black, reasonably insect-resistant heartwood (inside) and light-colored sapwood (outside) susceptible to fungal and insect attack;
Photo: U. Scharnow

Bark is the outer sealing tissue of trees, which primarily produces cork. The outer tissue layers die and then form the bark. The bark of some trees provides valuable goods, e.g. tannins (acacia, Brazil wood and oak bark), spices (cinnamon), pharmaceuticals (cinchona bark, cascara, quebracho bark) and cork (cork oak) (see Fig. 168).

Figure 168: Cork bark from the cork oak (Quercus suber);
Photo: U. Scharnow

Lumber and bark have water contents of approx. 4 to 30% and belong in water content class 2 (WCC 2).

They are goods displaying 3rd order biotic activity (BA 3), because their respiration processes are suspended but their biochemical, microbial and other decomposition processes still proceed.

Roundwood is frequently transported while green and thus with very high moisture levels. If several of these containers are loaded in one hold, elevated CO_2 concentrations or oxygen shortages may arise as a result of decomposition processes.

Requirements with regard to storage climate conditions are dependent on the range of shapes carried and the packaging used, which may range from loose transport to transport in crates or cases (bark also in bags and bales), i.e. some products may be exposed without protection to atmospheric influences while others require particular temperature humidity/moisture and possibly ventilation conditions (SC VI).

In connection with this, fitness for container transport has also to be assessed and extends from lo/lo transport using open-top containers through flatracks, platforms to standard containers and special containers ("logtainers").

Special export and import certificates are often required for lumber and especially tropical lumber. These certificates prove, for example, that the lumber has been felled from a managed forest and guarantee that the it originates from forestry operations which have been certified to operate responsibly by an independent and recognized certification organization.

Transport instructions and damage
All types of lumber, whether processed or unprocessed, are carried in containers. Lumber is transported as roundwood (round lumber, log, see Fig. 169) and cut lumber (see Fig. 170).

Figure 169:
Roundwood, strapped together into bundles;
Photo: U. Scharnow

Figure 170:
Cut lumber, strapped together into packages;
Photo: U. Scharnow

Veneers and sheets are transported in cases, crates or steel strapping with edge protection or on pallets. Veneers are thin sheets of lumber 0.6 - 6.0 mm thick used as a decorative covering for furniture. Veneers are a valuable cargo, especially when produced from rare or exotic wood species.
Bark is transported in bags, bales, barrels and cases.

Hygroscopicity
Due to lumber's high pore content, it is regarded as a porous material having lumens filled with water or water vapor. Lumber is classified as follows on the basis of its water content (Table 27).

Designation	**Water content in %**
Kiln dry lumber	0 - 6
Room dry lumber	6 - 10
Very dry lumber	10 - 12
Air dry lumber	12 - 15
Slightly dry lumber	15 - 20
Green lumber (forest dry)	20 - 25
Fiber saturated lumber	30 - 33
Water saturated lumber	> 33

Table 27: Water content of lumber in %

Fiber saturation means that the cell walls are maximally filled with water, while water saturation means that all lumens are maximally filled with water.

Air dry lumber is considered dry for shipment; its equilibrium moisture content is
70 - 80% at a temperature of 20°C (see Fig. 171).

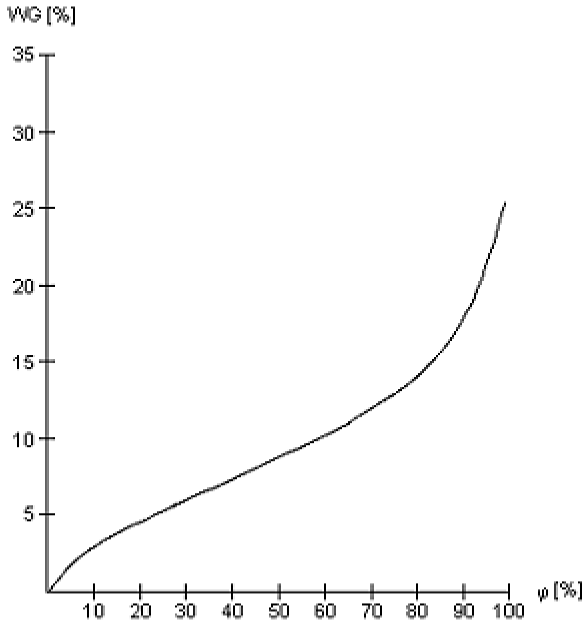


Figure 171: Sorption isotherm for lumber, air dry (20°C)

Bark must be protected in particular from all forms of moisture (seawater, rain, condensation water), since it tends easily to mold growth and spoilage. The water content of cork bark, for example, is 4 - 5%, while the equilibrium moisture content is 65 - 70% at 20°C.

The lumber "works", i.e. swells as it absorbs moisture and shrinks as it dries. Storage in the sun may cause dry splitting due to drying as result of solar radiation.

If palletized veneers exhibit moisture damage from the outside only, a leak may have occurred. If the container was checked for leaks before acceptance of the load, it may be assumed that the damage occurred during prior storage or due to dripping sweat in the container.

Exposure to humidity/moisture may cause veneers in particular to develop a tendency to waviness and to degluing of sheets.

There are three causes for waviness of veneer:

1. If the veneers are dry and also exhibit no moisture stains, a production error (excessively rapid drying) may have been the cause.

2. If stains and rings are visible, but the veneer is nevertheless dry and wavy, it is to be suspected that the veneer has become damp during storage prior to container transport and has redried.

3. If the veneer is still wet and wavy, the damage may have occurred during transport or storage. In the latter case, the truck or container must have been leaky or loading was carried out in rain. The more tightly are the veneers compressed on the pallets, the lower is their sensitivity to external influences.

Density
A distinction is drawn between theoretical density and apparent density. Theoretical density is calculated purely on the basis of solid lumber, i.e. as if all cavities within a slab of lumber had been obliterated by compaction. Theoretical density is identical for all species of wood and is 1.50 g/ cm³. Apparent density or bulk density is calculated from the weight and the volume of the lumber and differs from species to species in accordance with their differing structure. Comparisons can only be made between types of lumber with an identical water content. Fixed points are a water content of 0% (kiln dry lumber) and 15% (air dry lumber, see also Table 28).

Category	**Density in g/cm³**
very light species	< 0.40
moderately light species	0.41 - 0.50
light species	0.51 - 0.60
moderately heavy species	0.61 - 0.70
heavy species	0.71 - 0.80
very heavy species	> 0.80

Table 28: Classification of lumber types by density

Balsawood with a density of 0.14 - 0.44 g/ cm^3 is the lightest lumber, while quebracho (1.12 g/ cm^3), ebony (1.18 - 1.33 g/ cm^3) and guayac (1.20 - 1.30 g/ cm^3) are among the very heavy species.

Measures for maintaining quality
To protect lumber from damage

- mechanical means and
- chemical lumber preservatives

may be used.

Sheet steel protectors are applied around the cross-section of the log in order to prevent splitting due to drying-out of the lumber. In the case of woods with a high tannin content, however, this may result in oxidative discoloration. In order to inhibit splitting, oxidative discoloration and fungal attack, the cross-sections or bark-free surfaces of the logs are preserved immediately after felling with wax, paraffin, latex or lime, e.g. limba, Parana pine; limba is generally limed.

Damage

Mechanical damage
Splitting due to shrinkage caused by drying-out degrades quality considerably. There is a risk of frost splitting at temperatures below freezing point, e.g. in the case of ilomba and African canarium.

Lumber is at the greatest risk of mechanical damage when being packed into and unpacked from the container. In addition, inadequate cargo securing very often leads to damage to sensitive edges and corners of veneer packages. To prevent mechanical damage to the packages, fit for purpose packaging is absolutely essential, as is correct and proper handling of the goods. Particular attention should be paid here to edge protection and modular unit load dimensions. Correct edge protection ensures that the veneers survive undamaged slightly rough handling during packing and unpacking. Container modularity ensures tight packing of a container and thus allows the cargo to be secured for the most part without additional expenditure.

The packages should have bases that resemble pallets, so that they can be readily handled using ground conveyors. If packages have to be packed lengthwise into the container, it must be ensured that ground conveyors can gain access under the pallet bases even from the narrow side. This ensures that it is possible to avoid any damage arising from "pushing" or "pulling" of the packages.

Hazards to health
Over 30 different types of lumber contain irritants or poisons, e.g. khaya, African padouk, amarante, beté, jarra wood, guayac, makore. Care must be taken in the event of splinter injury owing to the risk of skin inflammation (dermatitis).

Damage caused by pests and fungal attack

Insect infestation
The nature and duration of non-containerized precarriage have a major impact on the quality of tropical structural lumbers due to pests and fungal attack.

"Worminess" is the result of burrowing by wood-destroying insects (beetles, horntails and wood borers). The soft sapwood is particularly susceptible. Dressed lumber is consequently not at such high a risk.

Particular attention must be paid to termite infestation of tropical roundwood. Termite-infested lumber has "galleries" or tunnel-like systems of passageways. Imported exotic hardwood logs must always be inspected for termite infestation. Termite-resistant wood species are, for example, jarrah, East-Indian rosewood, teak and izombé.

Fungal attack
Fungi which may attack tropical structural lumber include

- wood-destroying fungi, which may cause "white rot", "red rot" and "brown pocket rot", and
- wood-discoloring fungi, which cause blue discoloration, among other things.

Fungal attack, especially by blue stain fungi, may considerably reduce the quality of veneer, especially sapwood, during the voyage. The optimum temperatures for blue stain fungi are 27 - 30°C; this optimum coincides with the optimum for wood-destroying insects. Wood-destroying fungi have an optimum of 33 - 40°C. Both groups experience optimum development at a relative humidity of 85 - 95%. Sapwood is preferred by fungi due to its content of sugar, starch and protein (see Table 29).

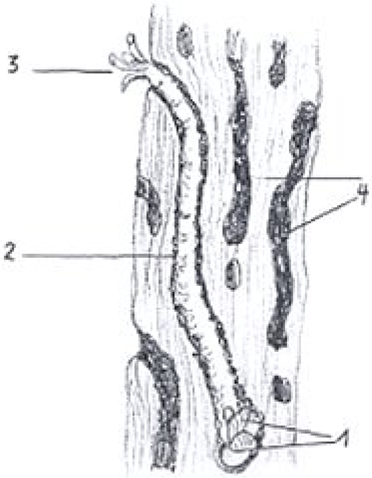
	Optimum temperature	Water content for lower growth threshold	Optimum equilibrium moisture content
Blue stain fungi	27 - 30°C (max. 35°C)	30 % (fiber saturation point)	85 - 95 %
Wood-destroying fungi	33 - 40°C	20°C	85 - 95 %
Hygrophilic molds	37°C	moist to wet surfaces	95 - 99 %
Wood-destroying insects	27 - 30°C	at least 15% air in pores of the lumber	> 75%

Table 29: Optimum temperature and humidity/moisture requirements of wood-damaging fungi and insects

Figure 172: Breakwater pile of pinewood, destroyed by pile- or shipworm (Teredo navalis);
Photo: Ragna Scharnow

Figure 173: Pile- or shipworm (Teredo navalis)

1 - head end with bivalve shells
2 - worm-like body
3 - tail end
4 - further burrows



Rafted logs may be infested by bivalves and crustaceans (e.g. balanids). Destruction of the lumber by bivalve teredos proceeds very rapidly due to the large number of individuals (see Figs. 172, 173). Only few wood species are considered teredo-resistant, e.g. ekki, teak and acariquara (see Fig. 174). The latter are therefore used for breakwater construction.

Figure 174: Acariquara logs from Brazil, which are teredo- and salt water-resistant, have a fibrous structure and cavities. Several of the logs are strapped together into bundles.
Photo: U. Scharnow

19.2 Fibers

Characteristics and fitness for container transport

"Fibers" is the collective term for all kinds of fine fibers and filaments. Fibers are used as a starting material for clothing, household textiles and industrial goods.

Fibers are divided into natural and manmade fibers.

With water contents of 5 - 14%, fibers, especially those of vegetable origin, belong to water content class 2 (WCC 2). Due to their processing, they are goods in which respiration processes are suspended, but in which biochemical, microbial and other decomposition processes still proceed; they thus exhibit 3rd order biotic activity (BA 3). Fibers require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI).

Fibers are transported in standard containers, subject to compliance with limits for water content of goods, packaging and container floor.

Transport instructions and damage

Packaging
Fibers are usually transported in bales, which are compressed to different degrees and are tied firmly with steel straps or wire. To protect bales from contamination and damp, they are wrapped in jute or plastic fabric, and perforated plastic films are also used to regulate bale moisture content. Care must be taken during container stuffing to ensure that the bale strapping is not damaged. Undamaged strapping is essential to maintain compression of the bales during transport. If the strapping is broken, compression is diminished, which results in an increased supply of oxygen to the inside of the bales. This in turn increases the risk of self-heating/spontaneous combustion of the bales.

Hygroscopicity
Table 30 shows the water contents for some natural fibers.

Natural fiber	Water content in %	Equilibrium moisture content in %
Cotton	7.85 - 8.50	65
Esparto	7.00 - 14.00	65
Flax	10.00 - 12.00	65
Flax tow	10.00 - 12.00	65
Hemp	10.00 - 12.00	65
Jute	12.50 - 14.00	65
Kapok	8.50	65
Coconut fiber	12.00	65
Manila hemp	5.00 - 12.00	55
Palm fiber	12.00	65
Piassava	16.00	70
Raffia	12.00	65
Ramie	7.50 - 12.00	65
Sisal hemp	5.00 - 12.00	55
Chair cane (Rattan)	10.00 - 12.00	65
Absorbent cotton	7.85 - 8.500	70

Table 30: Water contents of some natural fibers

Natural fibers must be protected from all forms of moisture, whether excessive humidity or seawater, rain or condensation water, in order to prevent decay, discoloration, mold, mildew stains and rot. When exposed to moisture, fibers tend to discolor rapidly, ultimately turning black, they assume a musty odor and become moldy and

mildewed; they lose tensile strength and elasticity and, to a greater or lesser degree, become susceptible to decay. Where bales are strapped with steel straps or wires, corrosion and consequently rust damage may occur.

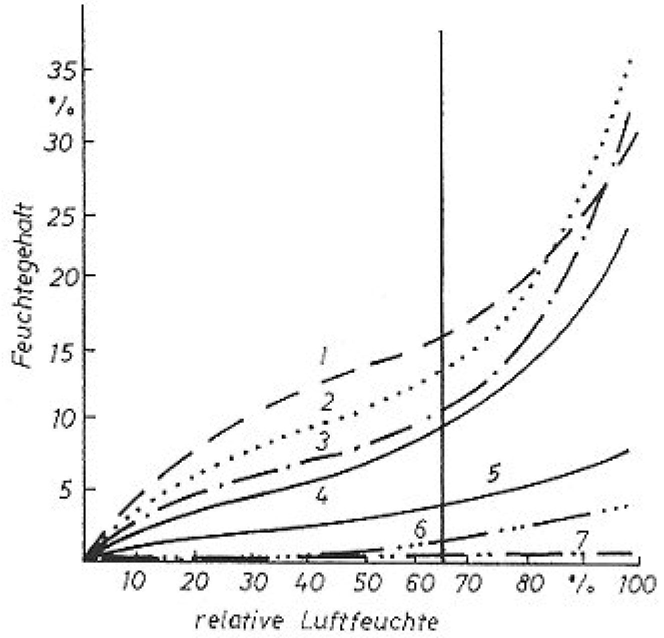


Figure 175: Sorption isotherms for various fibers [4]

1 - Wool
2 - Viscose
3 - Natural silk (Bombyx silk)
4 - Cotton
5 - Polyamide 6
6 - Polyacrylonitrile fiber
7 - Polyester fiber

Fig. 175 shows the sorption isotherms for some fibers. These show that natural fibers, such as cotton, wool and Bombyx silk, exhibit markedly hygroscopic behavior, while manmade fibers exhibit lower hygroscopicity. Natural fibers may absorb large quantities of water vapor without feeling damp. At a relative humidity of 95%, cotton, for example, may increase its water content to 25 - 27% without feeling wet. Swelling may cause cotton bales to increase in volume by 40 - 45%. Such levels of swelling can make containers burst.

Fiber	**Swellability in %**
Cotton	40 - 45
Flax	up to 20
Hemp	up to 30
Jute	up to 34
Wool	up to 30
Natural silk	20 - 40
Asbestos	0
Viscose fiber	85 - 120
Cuprammonium rayon fiber	85 - 120
Acetate fiber	20 - 25
Glass silk	0
Polyvinyl chloride fibers	0.1
Polyacrylonitrile fibers	4.0
Polyamide fibers	13.0
Polyester fibers	3.0 - 4.0

Table 31: Swellability of various fibers

Fire hazard properties

Natural fibers and manmade fibers based on natural fibers have a tendency to undergo self-heating/spontaneous combustion (see Section 13.6). However, fires have also frequently been caused by external ignition. The root cause may be found in the structure of the fibers themselves: their high crude fiber content, which in the case of vegetable fibers consists of cellulose, accompanying substances, such as oils, fats and tallow, the influence of moisture, poor thermal conductivity and an oxygen supply, which is provided by the well-developed lumen of vegetable fibers or the medulla of animal fibers (see Figs. 176, 178). Another factor is the activity of microorganisms. Even traces of vegetable or animal oils or fats are sufficient to bring about self-heating by the degradation of organic substances. Wool, for example, can never be completely degreased.

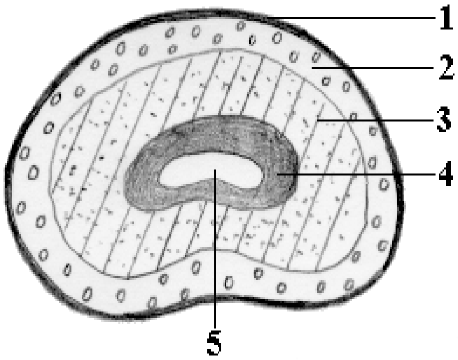


Figure 176: Cross-section through a cotton fiber [4]

1 - Wax layer
2 - Primary wall
3 - Secondary wall
4 - Tertiary wall
5 - Lumen

Figure 177: Ginned, i.e. deseeded, cotton; Photo: U. Scharnow

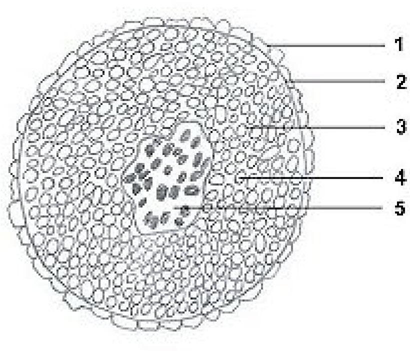


Figure 178: Cross-section through a wool fiber [4]

1 - Scale layer
2 - Intermediate membrane
3 - Cortical cell layer (cortex)
4 - Lanolin
5 - Medulla

There may often be a delay in identifying fires in fiber bales as the oxygen required for combustion is supplied by the air enclosed in the lumen or medulla, which is sufficient to maintain smoldering fires for weeks. Such fires are thus also difficult to extinguish, with CO_2, foam or the like being used. Water is not suitable as a fire-extinguishing agent due to the swelling it causes (see Table 30).

All natural fibers, with the exception of asbestos, share the following properties:

- a low ignition temperature, which means that sparks or an unextinguished cigarette end are enough for ignition
- rapid propagation of the fire to all bales in the event of external ignition
- deep penetration of the fire into the bales
- increased susceptibility to fire after contact with fats or drying oils

Figure 179:
Sisal drying station in Mexico;
Photo: Ragna Scharnow

Figure 180:
Sisal bales: fiber bundles are arranged in parallel in order to avoid breakage. The bales have no wrapping.
Photo: Ragna Scharnow

19.3 Paper & paper products

Characteristics and fitness for container transport
Paper is a flat material made essentially from fibers of predominantly vegetable origin by dewatering a fiber pulp (fiber suspension) to produce a fiber felt which is then compressed and dried. The most important fibrous raw materials are wood and waste paper. The following are types of paper:

- Printing and publication paper
- Office paper and stationery
- Paper, cardboard and paperboard for packaging purposes
- Sanitary paper
- Paper and paperboard for industrial and special purposes

Paper and paper products have water contents of between 6 and 10% and therefore belong in water content class 2 (WCC 2).

Due to their processing, they belong to the class of goods in which respiration processes are suspended, but in which biochemical, microbial and other decomposition processes still proceed; they thus exhibit 3rd order biotic activity (BA 3). Paper and paper products require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI).

Where paper is transported in containers, it is mostly standard containers that are used.

Transport instructions and damage

Packaging
Newsprint, paperboard, corrugated board and other types of paper are generally transported in rolls up to 300 cm wide and with a total weight of up to 4.5 metric tons. The circumferential packaging for the paper rolls wound ultratightly onto paperboard cores is up to 3.5 mm thick and, as a rule, consists of several plies of kraft paper. The circumferential packaging is folded over at the ends. The ends of the rolls are protected by paperboard covers. In many cases, the final kraft paper cover is plastic-coated and stuck to the folded-over circumferential packaging. It protects the roll if loaded vertically.

- Filter paper, waste paper and the like are predominantly transported in bales strapped with wire.

- Photographic paper, waxed paper and the like are transported in solid wooden cases.

- Sheet paper is wrapped in packing paper and the packages are strapped to pallets with steel strapping.

Hygroscopicity
As paper is mainly made from vegetable fibers, it is hygroscopic and has a tendency to swell. Improper storage may result in dimensional changes, distortion and reduced strength.

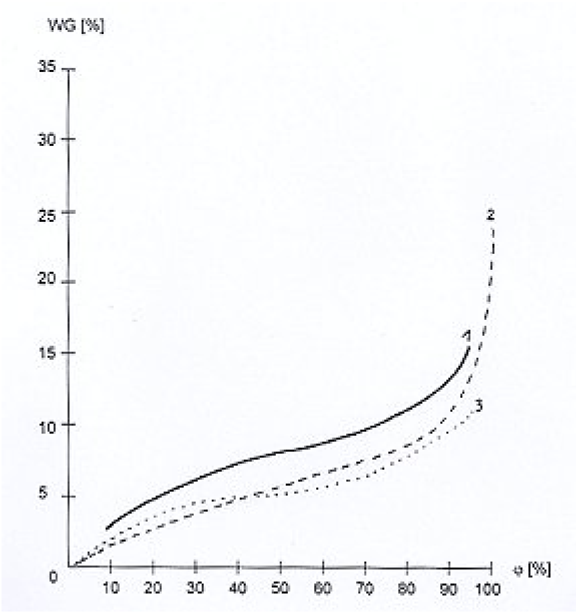


Figure 181: Sorption isotherms for various types of paper

1 - glassine paper (20°C)
2 - paper (20°)
3 - filter paper

The water content of paper amounts to 6 - 10%, depending on the type; this value stays constant at the storage climate of 20°C + 5°C most favorable for these materials and a relative humidity of 65% + 5%. Fig. 181 shows examples of sorption isotherms for various types of paper.

	Type	Water content in %	Rel. humidity in %
1.	Waste paper	6 - 12	65 - 70
2.	Filter paper	5 - 8	65 - 70
3.	Cardboard:		
	Chromo imitation board	5 - 8	65 - 70
	Chromo board	6 - 9	65 - 70
	Folding carton board	9 - 12	65 - 70
	Cup board	6 - 8	60 - 70
4.	Packing paper	5 - 9	65 - 70
5.	Paper bales	6 - 10	65 - 70
6.	Millboard	8 - 10	65 - 70
7.	Waxed paper	5 - 9	65 - 70
8.	Corrugated board	8 - 14	65 - 70
9.	Newsprint	6 - 10	60 - 70

Table 32:
Water contents and equilibrium moisture contents for paper and paper products

During cargo handling, paper and paper products must be protected from all forms of moisture, as there is a risk of losses caused by swelling and tearing of individual layers. To protect paper from dripping sweat in the container, a nonwoven fabric should be attached beneath the container roof.

Condensation water is particularly likely to occur during voyages from cold to hot climates (Scandinavian ports, Continental ports - tropical unloading ports in Africa, Asia) or during unloading of the paper in tropical ports if the goods could not be sufficiently warmed up during the voyage and were exposed to the hot ambient air upon opening of the container doors. Condensation ("cargo sweat") occurs on the goods (see Section 10.3.5). One loss prevention measure which could be taken in such an instance would be to leave the containers standing for two to three days in the warm environment, until the rolls of paper have adapted to the ambient temperature. This "warming up" of the cargo, until its temperature is higher than the dew point of the ambient air at the receiving point, may be shortened or omitted if the container has been transported on deck and has thus been able to adapt to the air temperature at the port of discharge. Unfortunately, little or no influence is to be had over container stowage positions on the ship, despite the latest developments in data processing.

Wetting damage may also arise as a result of wet set-down surfaces during storage. The container floor must not be too damp. A maximum water content of 15% should not be exceeded. Swelling caused by wetting may lead to a 50-

70% increase in volume, resulting in swelling and bursting of the outer layers to a considerable depth and rendering several hundred layers of paper unusable.

Moisture- or wetness-damaged paperboard, paper, filter paper and cardboard goods suffer quality degradation. This is revealed externally by distortion, torsion, changes in smoothness and color, reduction in mechanical tensile strength and waviness.

If the water content of paperboard falls to < 8% and that of cardboard goods to < 5%, brittleness and shrinkage of the fibers occur. Since stacked sheets cannot enter into a free exchange of moisture with the ambient air, this equalization is limited to the edges in contact with the air. This causes bulging of the edge areas and buckling of the board, which is promoted in particular by intense solar radiation (see Fig. 182).

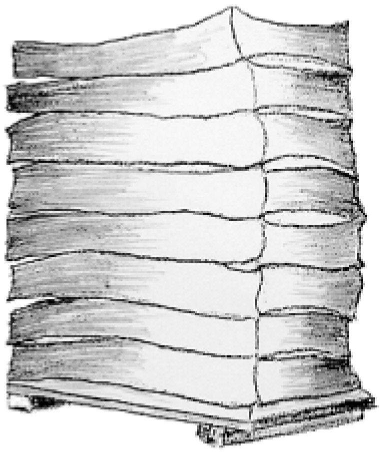


Figure 182:
Buckling of paper
on a pallet

Temperature and fire hazard
The favorable travel temperature range is 0 - 25°C. Care must be taken if paper packages on pallets are exposed to the sun: they lose moisture and the resultant drying-out causes the outsides to shrink, leading to bulging and bending (buckling).

Paper, paperboard and waste paper in stacked bales tend towards heat-induced spontaneous combustion. The autoignition temperature is 100°C. The cargo must be protected from sparks and smoking must be prohibited during the packing and unpacking of containers.

Roofing felt, which is impregnated with bituminous impregnating agents (tar, asphaltic bitumen) can be ignited by a match flame. When stacked, fresh roofing felt has a tendency to heat-induced spontaneous combustion.

Mechanical damage
Mechanical damage arises as a result of pressure, impact, friction (chafing) and unsuitable handling equipment. Only special cargo handling gear, such as clamp lift trucks and rotating clamp lift trucks, should be used for handling rolls of paper.

Mechanical damage may arise when transporting palletized goods, especially during packing and unpacking of the container using forklift trucks. If, for example, excessively long forks are used on the forklift trucks which project on the other side of the pallet, other items of cargo may be damaged if the pallet is loaded closely up against them. Incorrect cargo securing creates the greatest risk of damage. On the one hand, the cargo may be damaged by the cargo securing itself, and on the other hand inadequate cargo securing provides considerable scope for damage. Cargo securing should always be absolutely tight.

- Indentations
  Indentations cause damage as far as they extend into the paper layers. It is therefore essential that no cargo residues or residual material from previous cargo securing remain in the container and that there are no unevennesses.

- Edge and tear damage
  Edge and tear damage arise as a result of shocks and impacts. Although the damage may often look slight on the outside, once the packaging is removed paper loss often proves considerable, as the snagged layers are unsuitable for processing. Snagging makes the layers unusable over the depth of the snags; they are torn off (stripped down) and used only as waste paper (see Fig. 183).

Figure 183: Tear damage to paper rolls results in considerable paper losses, as the rolls become unusable to the depth of the snag.
Photo: U. Schieder

The percentage loss caused by snags to rolls can be determined according to the following formula (see Figs. 184, 185):

$$S = \frac{400 \times T(D-T)}{D^2 - d^2}$$

in which
T = depth of snag
D = diameter of roll
d = diameter of core
S = diameter loss in %

Figure 184: Formula for determining percentage loss in the case of snagged rolls [59]

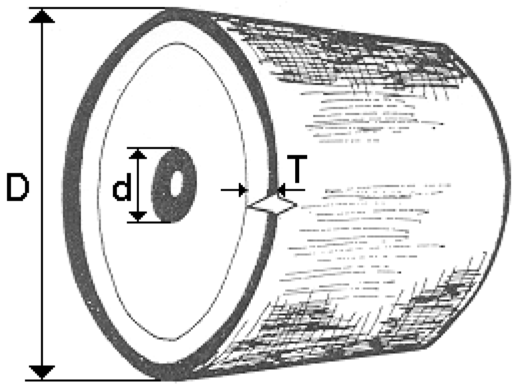


Figure 185: Diagram for calculating paper loss in the case of damaged rolls [59]

T = depth of snag
D = diameter of roll
d = diameter of core

Table 33 provides an overview of the extent of losses suffered as a function of the depth of damage:

Depth of damage	Roll diameter		
	91 cm	95 cm	100 cm
3.0 cm	12.91%	12.37%	11.76%
4.0 cm	17.02%	16.31%	15.52%
5.0 cm	21.02%	20.17%	19.19%

6.0 cm	24.94%	23.93	22.79%
7.0 cm	28.75%	27.61%	26.30%
8.0 cm	32.47%	31.19%	29.74%
9.0 cm	36.08%	34.69%	33.09%
10.0 cm	39.60%	38.10%	36.36%

Table 33: Outcome of damage as percentage of roll weight with an assumed core diameter of 10 cm

19.4 Gums & resins

Characteristics and fitness for container transport

Origin
Most gums and resins originate in the tropics and are transported to temperate latitudes. Gums and resins are exudates from plants, usually in the form of solidified plant saps, such as asafetida, gutta-percha, gamboge. The hardened, rubbery mucilaginous sap from tropical acacias is known, for example, as gum arabic and balata gum. Gelatinous plant exudates include gum tragacanth, karaya gum. Examples of soft resins or balsams include damar, copal, rosin, Canada balsam. Montan wax is a fossil plant wax. Examples of tanning extracts include catechu black, gambir, quebracho extract, wattle extract, mangrove extract.

Gums and resins vary in color from white to yellow to brown.

Structure
Gums and resins are usually produced in the form of granules, roundish pieces (asafetida), often as brittle, crumbly pieces (damar, rosin, Japan wax, montan wax), rarely as powders (quebracho extract, gum arabic) or cast in sheets (shellac, gutta-percha).

Use
Gums, resins and extracts are used as tannins (myrobalan extract, gambir, catechu black, mangrove extract), in medicine (asafetida, gum arabic, damar), pharmaceuticals (gamboge), in the chemicals industry (paraffin, montan wax, rosin), in dyeing (gamboge, myrobalan extract), in adhesive manufacture (gum arabic) and for industrial applications (balata gum for drive belts, gutta-percha for electrical insulation).

Gums and resins contain only a little water and are classed in water content class 1 (WCC 1). Rosin belongs to water content class 0 (WCC 0) because its water content has been removed by steam distillation.

These are goods whose respiration processes are suspended but in which biochemical, microbial and other decomposition processes still proceed; they are thus goods which display 3rd order biotic activity (BA 3).

Gums and resins require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI).

If gums and resins are to be transported in standard containers, they must be container dry when supplied by the manufacturer. Stowage below deck should also be provided in order to avoid solar radiation, especially in the tropics, and the steep temperature gradients on deck. Unfortunately, little or no influence is to be had over container stowage positions on the ship, despite the latest developments in data processing. Ideal conditions would be provided by open-sided containers in well ventilated lower holds (protection from solar radiation and temperature variations), with the option of providing ventilation to prevent the formation of sweat.

Transport instructions and damage

Packaging
Gums and resins are transported in bags, cases, drums, rolls, bales and cartons on pallets (paraffin). Double-layered bags with a jute outer bag and plastic liner are mainly used (damar, copal).

Temperature
Gums and resins soften and melt at elevated temperatures.

No.	Name	Melting temperature
1.	Balata gum	becomes soft and plastic at 50°C and cakes in temperate latitudes.
2.	Benzoic resin	melting point at 75°C, sticks to case lumber.
3.	Damar	melting point at 84°C (hard grades), syrupy liquid at 120°C, soft grades of damar ferment readily.
4.	Gambir	solid appearance before loading; softens to a slimy mass, then cakes.

5.	Gutta-percha	begins to soften at 37°C, becomes plastic at 50 - 65°C, melts and breaks down at 120 - 130°C; cakes at low temperatures.
6.	Japan wax	begins to melt at 50°C.
7.	Candles:	temperature variations can make candles melt together, making them unsalable. 48 - 50°C
	Paraffin	53 - 54°C, releases oily substances on exposure to heat.
	- Stearin	50 - 54°C
	- Wax	60 - 80°C
8.	Rosin	softens at 55 - 83°C, melting point 100 - 130°C.
9.	Copal	rapidly softens, coalesces, ferments and cakes.
10.	Montan wax	melting point at 80°C
11.	Myrobalan extract:	tends to soften rapidly.
12.	- Paraffin, hard	melting temperature at 50 - 60°C
13.	- Paraffin, soft	melting temperature at 42 - 50°C
14.	Quebracho extract	when exposed to temperatures > 25°C tends rapidly to form lumps and stick together; cakes at < 5°C.
15.	Shellac	begins to flow at 40°C, cakes completely; risk of sheet breakage at 0°C.
16.	Wattle extract	begins to flow at 18 - 25°C, bags "weep" and then stick together; cakes at < 5°C.

Table 34: Melting temperatures of gums, resins and extracts [28]

Moisture
Gums and resins are generally water-soluble. They must be protected from all forms of moisture. Gum arabic, for example, forms a sticky, viscous solution when exposed to moisture, as does catechu black. Some (damar) start to ferment; gamboge dissolves. Copal, especially when fresh, suffers spoilage.

Gums and resins must most particularly not come into contact with seawater as this greatly impairs their subsequent use. Before the container is packed, it must therefore be subjected to a thorough tightness inspection. In order to provide protection from condensation, a nonwoven fabric which can absorb considerable quantities of water may be suspended in a standard container. While this cannot completely eliminate all risk of damage, the goods are at substantially lower risk of wetting. Benzoic resin, gutta-percha, paraffin and shellac are not water-soluble. Rosin is sparingly soluble in water.

Odor
Gums, resins and extracts may range from having an extremely strong odor to being virtually odorless. Asafetida or Devil's dung has a penetrating and nauseating odor due to its 6% content of sulfur-containing asafetida oil, an essential oil which smells of garlic. Benzoic resin releases an odor of vanilla or incense; resins primarily cause damage due to their resinous odor; balsam gum releases a turpentine-like odor, while jelutong gum has a rubber-like odor. Paraffin is virtually odorless.

Overall, most gums, resins and extracts cause odor-tainting, which means that containers must always be cleaned after unpacking. On the other hand, many gums, resins and extracts are odor-sensitive, such as gum arabic, benzoic resin, gum tragacanth, karaya gum and paraffin.

Contamination
Melting, flowing, stickiness due to exposure to heat or moisture may cause staining damage and discoloration. Mangrove extract makes red stains.

These goods are primarily susceptible to contamination by dust. Care must therefore be taken only to accept containers for packing which are absolutely clean.

Toxicity/Hazards to health
Some resins, such as gamboge, are toxic. Due to the benzoic acid esters it releases, benzoic resin is slightly to moderately toxic. Some resins consume oxygen, such as benzoic resin, damar, rosin, copal and shellac.

19.5 Hides, furs, leather goods

Characteristics and fitness for container transport

Hides are the raw material for the production of leather. Fig. 186 shows the structure of an animal hide. It is the dermis, which primarily consists of protein fibers, which forms the actual leather after removal of the epidermis and the subcutaneous tissue. Fig. 187 shows the component parts of a hide. The chemical composition of a green hide is: water 65%, protein 33%, fat 0.2 - 2% and mineral salts approx. 0.3%.

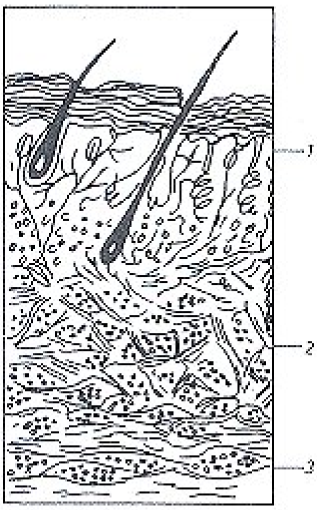


Figure 186: Section through an animal hide [27]

1 - Epidermis with hair
2- Dermis
3 - Subcutaneous connective tissue

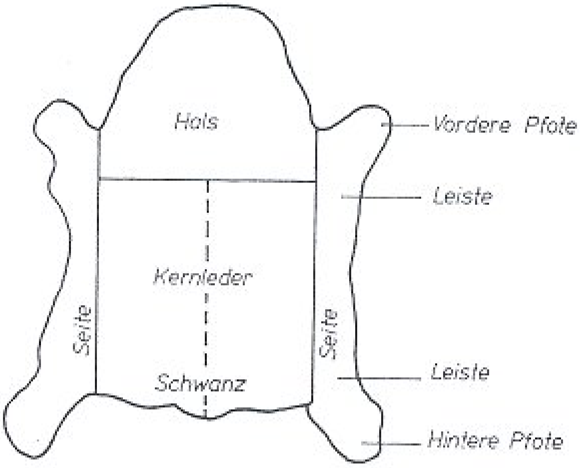


Figure 187: Component parts of an animal hide; Budzynska [7]

After removal from the body, the hide of large animals, such as cattle, buffaloes, horses and pigs, is generally preserved by drying or salting prior to further processing. Increasingly, it is the beamhouse product, i.e. the animal hide from which the epidermis and hairs and subcutaneous connective tissue have been removed, which is traded; this product is preserved by pretanning before it is sold.

Furs are the hides/furs of smaller animals, e.g. goats, sheep (lambs), foals, calves. The winter fur is fully mature, generally with a dense hair cover and thin leather; the summer fur has sparser hair and thicker leather. Furs are also preserved by drying, salting, curing or pickling.

Prime furs are valuable hides/furs of smaller animals, e.g. sable, mink, chinchilla, fox (red, blue, silver fox), Persian lamb, seal, otter, marten, ermine, muskrat, nutria.

Leathers are finished or dressed animal hides which have been subjected to tanning processes and are also known as "wet blue leather". Leather can be classed by hardness, ranging from hard leather for shoe soles to soft leathers for fashion accessories.

With low water contents of 10 - 30%, hides, furs and leather belong to water content class 2 (WCC 2). Due to their processing, fibers belong to the class of goods in which respiration processes are suspended, but in which biochemical, microbial and other decomposition processes still proceed; they thus exhibit 3rd order biotic activity (BA 3). They require particular temperature, humidity/moisture and possibly ventilation conditions (SC VI).

Furs and leather goods are transported in standard containers, subject to compliance with limits for water content of goods, packaging and container floor.

Methods for preserving hides
Due to the chemical composition of hides and fur which is favorable for bacterial and fungal growth, these goods are subject to rapid biological decomposition (rot, mold growth and mildew stains), which is associated with self-heating. They are thus preserved before transport; the commonest methods are

- drying
- dry salting
- wet salting

By removing water, the salt has preservative bactericidal and fungicidal action.

Transport instructions and damage

Packaging
Hides and furs are transported in bundles, packs or bales, while wet-salted hides are also carried in barrels or solid wooden cases lined with sheet metal or plastic film. Bales are usually compressed and tied with stainless steel or insulated wire. Leather is transported in bags, bales or cases, while finished products are shipped in cartons etc. or even in sales packaging.

Self-heating
Due to their chemical composition, hides and furs have a tendency to self-heating and spontaneous combustion. This behavior is partly determined by the natural fat content, which varies greatly as a function of animal species, breed, climate and nutrition.

Cattle hides	approx. 0.5 - 2%
Pig hides	approx. 5 - 30%
Goatskins	approx. 3 - 10%
Sheepskins	approx. 10 - 40%

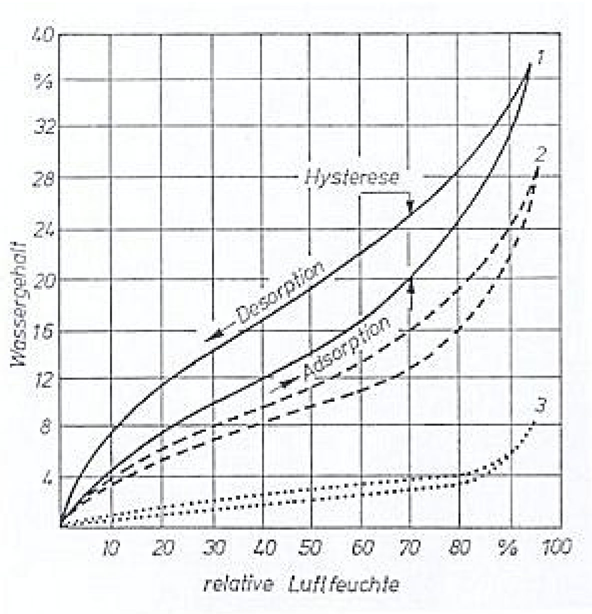
Table 35: Fat content of animal hides/skins

Due to the effect of heat and moisture and the impossibility of providing ventilation in standard containers, heat may build up, such that autoxidation processes resulting in self-heating may occur.

Optimum transport temperatures are 18 - 23°C.

Action of moisture
Exposure to moisture may result in rot, mold, mildew stains and hair loss in hides. The water contents of hides and furs are within the range 10 - 15% for dried furs, 15 - 20% for dry salted hides, 20 - 30% for wet salted hides and 12 - 17% for leather.

If storage conditions are excessively moist, i.e. at relative humidities of > 75%, leather tends to grow mold and suffer spoilage, while metal components (eyelets, buckles) on leather gloves and shoes will corrode (see Fig. 188).



Key:

Figure 188: Sorption isotherms for leather [27]

1 - Box cow/calf leather
2 - Vegetable/synthetic tanned cow and pig sole leather
3 - Foamed synthetic leather

If storage conditions for leather goods are excessively dry, i.e. at relative humidities of < 55%, drying damage may result in brittleness and cracking, which may give rise to complaints. Severe drying-out results in shrinkage in mass.

Contamination
Rust damage occurs after brief contact, especially with iron/steel. Containers must be completely clean, as contaminants could react with the hides. The painted finish of the container interior must be absolutely intact as contact with iron/steel components may result in reactions and irreversible damage. Containers with a special floor coating may have to be used as the strong smelling residues from hides are impossible to remove from a "normal" container floor.

Mechanical damage
Such damage often takes the form of snagging, which may be the result of improper handling. Incorrect stowage methods may result in kinking and creasing in dried hides.

Insect infestation and pathogens
In the event of moisture damage, look out for the development of maggots. Insect infestation may occur during precarriage or during brief storage prior to container packing. Maggots and beetle chewing damage result in serious damage to the hides. Hides may also contain anthrax spores. Appropriate certificates may be required.

19.6 Glass, porcelain & enamel goods

Characteristics and fitness for container transport

Glass is a hard, brittle material which has solidified from a melt in amorphous form. Window glass is machine-produced flat glass with an unblemished surface in thicknesses of 0.8 - 7 mm; it is also known as sheet glass.

Porcelain is a ceramic material primarily produced from kaolin and is usually traded as fineware.

Enamel is a solidified vitreous layer of inorganic composition fused onto a substrate, preferably of ferrous metal. A distinction is drawn between sheet and cast enamel goods. Sheet enamel goods include household articles, wall cladding, signs, while bathtubs are an example of cast enamel goods.

Glass, porcelain and enamel goods do not contain any water, and belong in water content class 0 (WCC 0). However, packaging materials belonging to water content class 2 (WCC 2) may be used (cases, crates, cartons, with internal packing of wood wool, paper, PU and PE foams as films and chips) (see Figs. 189, 190, 191). These materials must be container dry, so as firstly not to cause mold growth due to the release of moisture into the enclosed microclimate of the standard container and secondly to retain their strength. These are accordingly goods which require particular humidity/moisture conditions (SC IV).

Figure 189:
Pallet with ceramic pots, protected with paperboard interlayers and wrapped in plastic film;
Photo: Ragna Scharnow

Figure 190:
Bread crock in a corrugated board carton lined with corrugated board spacers;
Photo: Ragna Scharnow

Figure 191:
Shower trays packaged in corrugated board interlayers with edge protectors

Transport instructions and damage

Packaging to avoid breakage
Glass, porcelain and enamel goods are extremely fragile and so require particularly careful packaging.

Glass goods are packaged in cases using straw, wood wool or plastic foams. Window glass is best packaged in cases and/or in "A frames" which can be picked up on two or four sides by ground conveyors. Goods of large dimensions are packaged in crates or on frames, possibly using paper or plastic foams as separators between the individual sheets. Using inappropriate or no separators between the individual sheets results in scratching damage.

Porcelain articles should be wrapped in paper, wood wool or straw (N.B. hygroscopic) or packaged in plastic foams and are best transported in strong cases, for example made of wood.

Enamel goods also require careful packaging as the enamel coating can easily be chipped by mechanical influences. Good, strong internal padding is important. Relatively small articles are wrapped in paper and laid in cases which are padded with wood wool or plastic pellets; larger articles, especially the corners and edges, are secured with paper, straw or plastic pellets. Cases and crates should have good diagonal reinforcement and the walls should be sufficiently thick to prevent the contents from crushing. Crates should be of container "modular dimensions" so that they can be packed into containers with a tight fit. It is immaterial whether the tight fit in the container is achieved with just one case or crate or with several arranged side by side or one behind the other. Completely filling the container is the most effective way of securing the cargo and is especially preferred for such sensitive cargoes. Any remaining spaces must be filled.

Sensitivity to impact and jolting
Glass sheets should always be transported in a vertical position as they are more likely to break if stowed horizontally. Individual packages must be adequately marked with the symbols for fragile goods.

With enamel goods, a distinction should be drawn between flaking and chipping as causes of damage. "Flaking" is recognized in the enamel industry as a normal production defect, it being possible for small enamel parts to flake on exposure to low temperatures. "Chipping" due to impact, abrasion or other rough treatment of the enameled goods may result in losses.

Moisture
Although glass contains no water, it is sensitive to moisture. Depending upon a glass's resistance to moisture corrosion, i.e. to leaching of alkali metal oxides from the surface of the glass, it is assigned to one of five water resistance classes or hydrolysis classes. These hydrolysis classes are defined in German DIN standards and are tested using sulfuric or hydrochloric acid.

In one case, microscopes were transported in standard containers from a European port to Japan. On arrival, the lenses were found to have become cloudy due to the action of moisture. Investigations revealed that a fungal film had grown on them. Protection from all forms of moisture is thus required. Damage by microorganisms (microbial corrosion) depends upon the nature of the glass (acid class), the period of exposure to the microorganisms and the

level of relative humidity (φ). At $\varphi > 75\%$ or in a condensing atmosphere, droplets or spots of a blue-black deposit form on optical products. At $\varphi < 60\%$, the deposit is solid and can in most cases be removed by polishing.

One of the most dangerous kinds of deposit is the fungal film formed by fungal spores in a moist, warm environment at $\varphi > 75\%$. During growth, fungal hyphae have a water content of greater than 90% and are moreover strongly hygroscopic. Excretion of acids results in clouding or dulling of lenses.

Fungal films form less readily on any kind of glass which has been treated with fungicides (heavy metal salts, mercury salts). Surfaces which have been subjected to fungal attack must be reground and polished, providing that thickness tolerances permit. Otherwise, the parts are unusable and must be replaced with others.

19.7 Machinery, equipment

Characteristics and fitness for container transport

Machinery generally consists of a chassis (e.g. housing, frame, base) plus mobile machine components and electronic modules.
Machinery contains no water (WCC 0). Packaging may consist of box lumber or paperboard and has a water content of < 30% (nbsp WCC 2). This relatively high water content is problematic for much machinery and equipment due to its sensitivity to corrosion. Since corrosion may begin at a relative humidity of as low as > 40%, most machinery and equipment must be protected from this humidity/moisture by various corrosion protection measures and methods (humidity/moisture and possibly ventilation conditions SC IV). While ventilation may reduce the risk of corrosion, it is not in itself an effective method of providing corrosion protection. For this reason, all goods which are at risk of corrosion must be specially protected. Such goods should be transported in standard containers, subject to compliance with limits for water content of packaging and container floor.

Transport instructions and damage

Packaging
Machinery is usually transported in cases or crates of a size appropriate for the machine's dimensions. Cases are mainly made from softwood (e.g. spruce, pine, poplar) in accordance with recognized guidelines (e.g. HPE standards).

Machinery is often attached to pallets, while associated components are packaged in cartons and likewise attached to the pallet (see Fig. 192).

Figure 192:
Machinery attached to pallets, components packaged in cartons likewise attached to the pallet.

To provide protection from corrosion, machinery is enclosed in plastic film which is impermeable to water vapor (see Figs. 193, 194). Care must be taken to ensure that the film remains completely undamaged. Sharp corners must be carefully padded as the film package must be absolutely impermeable to water vapor. Particular care must be taken at any points where the film must be punctured, e.g. where the machinery is bolted to the case bottom. A rubber seal must be provided on both sides anywhere where the film has to be punctured, e.g. around a bolt to the case bottom. The film enclosure isolates the packaged equipment from the ambient air, so making it possible to exercise long-term control over the "microclimate" inside the package. A calculated quantity of desiccants ensures that relative humidity cannot rise above 40%, so stopping corrosion in its tracks (desiccant method).

Figure 193:
Undismantled large machine; sensitive parts enclosed in plastic film

Figure 194:
Undismantled large machine; sensitive parts enclosed in plastic film

Bolting machinery to case bottom, sealed package (see Fig. 195).
Machinery which is to be shipped in containers must always be provided with packaging which is fit for purpose. This particularly applies if the machinery is not being transported in a door-to-door container. An exception can be made if the machinery is being transported in a door-to-door container (FCL). In order to minimize cargo securing requirements within the container, it is advisable to tailor to the case bottom to the internal dimensions of the container (modularization), so making it possible to achieve a tight fit stow. Any cargoes which are at risk of tipping must always be additionally secured. Nailing cargo down to the container floor is not an acceptable cargo securing method.

Figure 195:
Sealed package with machinery enclosed in water vapor-impermeable plastic film and bolted to the pallet in such a way that the film is not damaged.

Machinery which is sensitive to impact may be protected with shock absorbing materials, such as plastic foams (polystyrene (PS), polyurethane (PU) or polyethylene (PE). Control units, special tools, assembly aids, auxiliary substances, lubricants etc. are often provided with their own packaging and enclosed in the machinery case.

Machinery with a relatively low package weight can be transported in paperboard cartons, inside which the machinery is wrapped in oiled or VCI paper or in open-end bags, or cradled in molded polystyrene inserts, corrugated board or the like. High strength corrugated board is used in order to provide good puncture resistance.

The packages must also be properly marked in accordance with standard 4711 (see TIS). Slips of paper, placards and

the like should not be used as they can easily be torn off.

Corrosion

Corrosion begins at a relative humidity of 40% and rapidly accelerates at relative humidities of > 60% (see Fig. 196). Depending upon the sensitivity of the goods to corrosion, even the slightest rust film may result in total loss of the goods. Protection must accordingly be provided from all forms of moisture (seawater, rain, condensation water and excessive humidity). The most effective corrosion protection method, which can prevent corrosion, is to use desiccants in a package which is impermeable to water vapor. Where "liquid" corrosion protection agents are used (coating method), care must be taken to ensure for transport operations in the tropics that they have a high dropping point of > 80°C. If the dropping point is low, there is a risk that the corrosion protection agent, which is of a solid consistency in temperate latitudes, will drip or run off the surfaces to be protected and will thus be unable to perform its protective task.

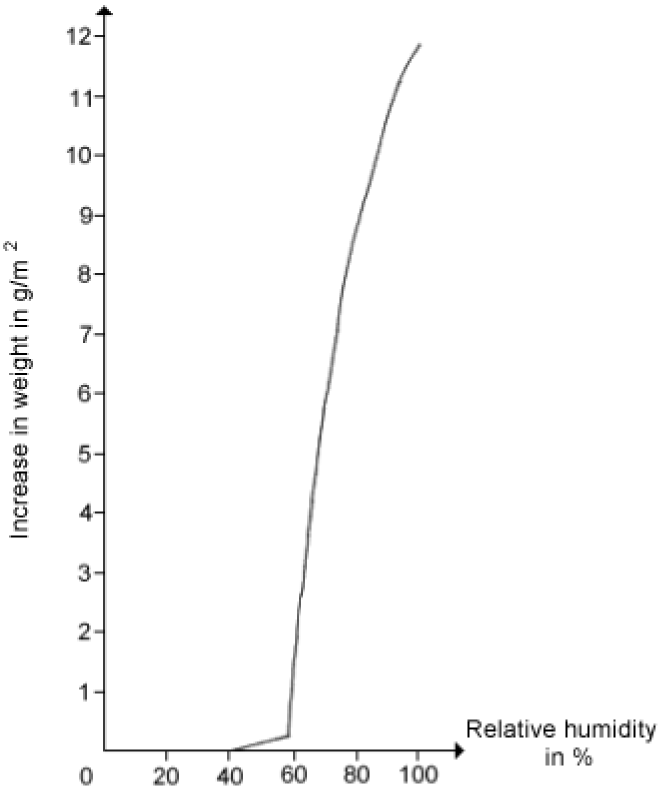


Figure 196: Ferrous corrosion as a function of relative humidity; 0.01% SO_2 content; duration of test, 55 days.

Another corrosion protection option is the VCI method. Volatile corrosion inhibitors are chemicals which are introduced into the packaging on a substrate, for example paper. The substances evaporate continuously and are deposited on the surface of the goods, where they displace the oxygen and so provide corrosion protection. Unlike with the desiccant method, packaging does not need to be hermetically sealed. It is generally sufficient to wrap the goods in film. The various VCI agents do not provide equally good protection for all metal alloys. They must be tailored to the particular product in order to be able to guarantee perfect corrosion protection. If many different metals and alloys have been used in a piece of equipment, the desiccant method is the most reliable corrosion protection method.

The American Rust Standard is very frequently used in international trade to describe the degree of rusting.

The degree of rusting of steel consignments should be recorded in the shipping documents before the container is packed, possibly using the following definitions:

- Wet before shipment
- Partly rust stained to rusty
- Gear marked
- Contaminated by foreign substance
- Contaminated by saltwater
- Chafed in places
- Packing torn exposing contents

When the desiccant method is used, if lumber is used for cargo securing or as accompanying material and is enclosed within the sealed package, the moisture content of such materials must be taken into account when calculating the necessary quantity of desiccants. Unless specially dried lumber has been used, the water content of lumber is generally so high that a disproportionately large quantity of desiccants must be enclosed in the packaging. It is thus advisable to carry out cargo securing measures outside the sealed package.

Temperature
If the temperature falls below freezing, frost damage may occur, e.g. due to ice expansion rupture at points where condensation, water drips and drainage water have collected. Lubricating or insulating oils assume an ointment-like consistency and it is thus best to use oils with a high solidification point or multigrade oils. Rubber conveyor belts or cable insulation may become brittle and break.

Insect infestation
Insect infestation need not generally be expected; however, damage may be caused to the packaging by creatures which mistakenly find their way in, such as beetles and beetle larvae. In their search for new breeding grounds, pests can destroy the packaging.

The common packaging materials paper and paperboard (corrugated board is the most susceptible) and most plastic films do not offer full protection against insect infestation. Creased packaging materials exhibit lower resistance than smooth materials because insects preferentially attack folded materials.

Before packing, the container must be examined for the absence of pests. Insect-resistant packaging is preferred. When wooden packaging materials or cargo securing materials are used, it may, under certain circumstances, be necessary to comply with the quarantine regulations of the country of destination and a copy of the wood treatment certificate may have to be placed in a highly visible location on the container. In the case of container transport to Australia and New Zealand, proof of adequate treatment against the sirex wasp must be provided.

In some cases, problems with rodents may arise during storage of the machinery before or after shipment. In particular, if such animals are unintentionally locked into the container on completion of packing, they can cause considerable damage to wiring, pipework etc., which may result in malfunctioning.

19.8 Electronic/electrical appliances

Characteristics and fitness for container transport
Examples of electronic/electrical appliances are

- household appliances ("white goods")
- home entertainment equipment ("brown goods")
- office equipment/communications equipment
- computers/computer peripherals, photocopiers, air conditioners
- precision mechanical/optical equipment (e.g. microscopes, cameras, enlargers)

Such appliances are manufactured and transported all over the world. Electronic/electrical appliances contain no water (WCC 0); however, the packaging material made from corrugated board or wood belongs to water content class 2 (WCC 2), the recommended upper limits for which must be complied with. These are accordingly goods which require particular humidity/moisture and possibly ventilation conditions (SC IV). Electronic/electrical appliances are goods which are at risk of corrosion and tend to suffer corrosion at relative humidities of 40%. In order to ensure that this hazard threshold is not exceeded, the packaging for the appliances must be container dry.

Such goods are transported in standard containers, subject to compliance with limits for water content of packaging and container floor.

Undamaged, dry containers must be used for transport. Packed containers should be closed with seals and the numbers recorded in the shipping documents.

Transport instructions and damage

Packaging
Electronic/electrical appliances are mainly transported in cartons, sometimes also in cases and crates, often using preformed foam inserts to secure the contents in the packages. Wood wool and corrugated board should no longer be used as internal packaging as they are hygroscopic (WCC 2) and there is a risk of condensation in the event of temperature changes. Non-hygroscopic packaging materials are best, i.e. foams which can neither contain nor absorb water (WCC 0), such as for example polystyrene, polyurethane, which are used in many different forms, for example as moldings (see Figs. 197, 198, 199) or as pourable chips (see Fig. 200) or they may be foamed in place. Airbags (see Fig. 201) and bubble film (see Fig. 202) are also effective. Goods which are palletized in accordance with the modular system and enclosed in sufficiently thick shrink film are favorable. Skids (sleds) are used for heavy packages.

Fig. 197:
Laptop computer in corrugated board carton with preformed polystyrene foam inserts to secure the contents;
Photo: Ragna Scharnow

Figure 198:
Home entertainment equipment (brown goods) with preformed polystyrene foam inserts to secure the contents;
Photo: Ragna Scharnow

Figure 199:
Home entertainment equipment (brown goods) with preformed polystyrene foam inserts to secure the contents;
Photo: Ragna Scharnow

Figure 200:
Plastic pellets as filling material;
Photo: U. Scharnow

Figure 201: Airbag;
Photo: Ragna Scharnow

Figure 202: Bubble film;
Photo: Ragna Scharnow

All packages must be labeled and marked in accordance with relevant standards. For example, "upside-down" stowage of such appliances may cause liquid to leak from pre-installed containers, resulting in a total loss (oil, chemicals, toner).

In the case of particularly high value and sensitive appliances, shock and/or tilt indicators should be attached. Such indicators may also have positive psychological effect, which should not be underestimated, encouraging careful handling of the goods.

Humidity/Moisture
Manufacturers generally specify very low relative humidities, e.g. 35 - 65%, for IT equipment. Water vapor adsorption may, for example, result in an increase in the self-capacitance of high frequency coils, or a reduction in the insulation resistance of paper capacitors or the dielectric strength of insulating materials. Such goods must accordingly be protected from all forms of moisture. Electrical products thus require particularly careful corrosion protection. No coating methods are usable, as coatings cannot be removed from sensitive appliances and fundamentally impair proper function. It is primarily the desiccant method which is used. Appliances are heat-sealed in film together with desiccants. Depending upon the composition of metals, the VCI method may also be used.

Contamination
Electronic/electrical appliances are extremely sensitive to contamination by dust. Absolute cleanliness is required in warehouses and containers which are to be packed. Dust in the air may result in damage. This sensitivity to contamination even extends to air pollution, in particular due to hydrogen sulfide (H_2S) (see Fig. 203). Hydrogen sulfide reacts with silver to form silver sulfide (Ag_2S), which results in the formation of a black film of insulating sulfides on the surface of silvered circuit contacts and relays and on silvered conductors (e.g. coils).

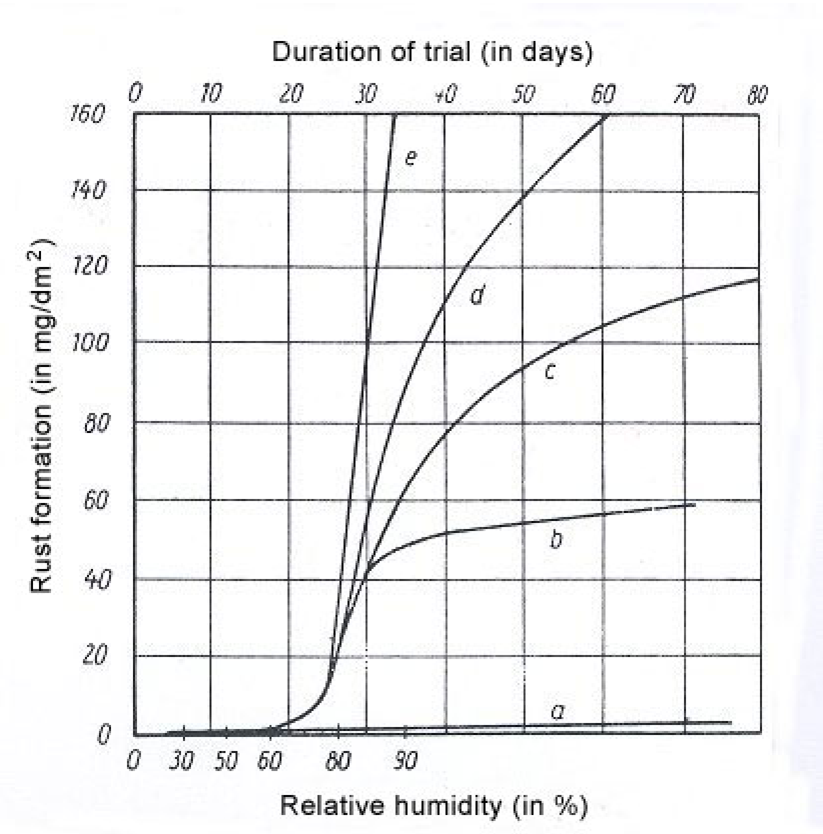


Figure 203:
Influence of relative humidity and air pollution on the rusting of steel;
Grundke [13]

a) pure air (even in the presence of charcoal particles)
b) traces of ammonium sulfate on the surface
c) traces of sulfur dioxide in the air
d) presence of ammonium sulfate and traces of sulfur dioxide
e) presence of charcoal particles and traces of sulfur dioxide

Sulfur dioxide (SO_2) and sulfur trioxide (SO_3) also have a corrosion-promoting action if these gases are dissolved in mist droplets; combined with water, they form H_2SO_3 or H_2SO_4.

Sensitivity to impact and jolting
Proper stowage and cargo securing within container, especially for LCL containers, together with compliance with stowage and handling symbols are absolutely essential.

The use of shrink film is advisable for palletized goods. Improper stowage has a serious impact on container shipments; problems include exceeding the maximum stacking height, incorrect cargo securing within the container, as well as damage caused by forklift trucks during packing and unpacking of the container and inadmissible hard impacts.

Heavy packages such as air conditioners and photocopiers are particularly sensitive to impact and vibration. Such packages should be placed on vibration dampers.

When packing and unpacking containers with ground conveyors, care must be taken to protect the appliances from battering. Especially when switch cabinets or large appliances are mounted directly on a pallet and are there enclosed in a sealed package, handling must be carried out with extreme care as damage to the sealed package would make the corrosion protection measures ineffective.

Risk of theft
Electronic/electrical appliances are extremely valuable, consumer-oriented goods which are consequently at considerable risk of theft. As a result, such cargoes are not only of interest to opportunist thieves, but are increasingly attracting international criminal organizations. It is not unusual for entire container loads to be taken or fraudulently diverted to other "receivers". This is often achieved thanks to insider information or illegal access to transport data and hacking into internal computer networks.

Company names and appliance details printed on packaging increase opportunist theft and such details should accordingly remain neutral (see Fig. 204).

Figure 204:
This detailed information invites theft.
Photo: Ragna Scharnow

In the case of theft, packaging units are often cleverly manipulated. Before goods are packed into the container, it should therefore be checked that the packaging is still in its original state. Providing that circumstances permit (e.g. customs inspections/checks of metal seals), the containers should be stowed with the doors of adjacent containers facing towards each other.

Insect infestation
Insect infestation need not generally be expected; however, damage may be caused to the packaging by creatures which mistakenly find their way in, such as beetles and beetle larvae. In their search for new breeding grounds, pests can destroy the packaging.

The common packaging materials paper and paperboard (corrugated board is the most susceptible) and most plastic

films do not offer full protection against insect infestation. Creased packaging materials exhibit lower resistance than smooth materials because insects preferentially attack folded materials.

Before packing, the container must be examined for the absence of pests. Insect-resistant packaging is preferred. When wooden packaging materials or cargo securing materials are used, it may, under certain circumstances, be necessary to comply with the quarantine regulations of the country of destination and a copy of the wood treatment certificate may have to be placed in a highly visible location on the container. In the case of container transport to Australia and New Zealand, proof of adequate treatment against the sirex wasp must be provided.

In some cases, problems with rodents may arise during storage of the appliances before or after shipment. In particular, if such animals are unintentionally locked into the container on completion of packing, they can cause considerable damage to packaging, casings and possibly pipework etc., which may result in malfunctioning.